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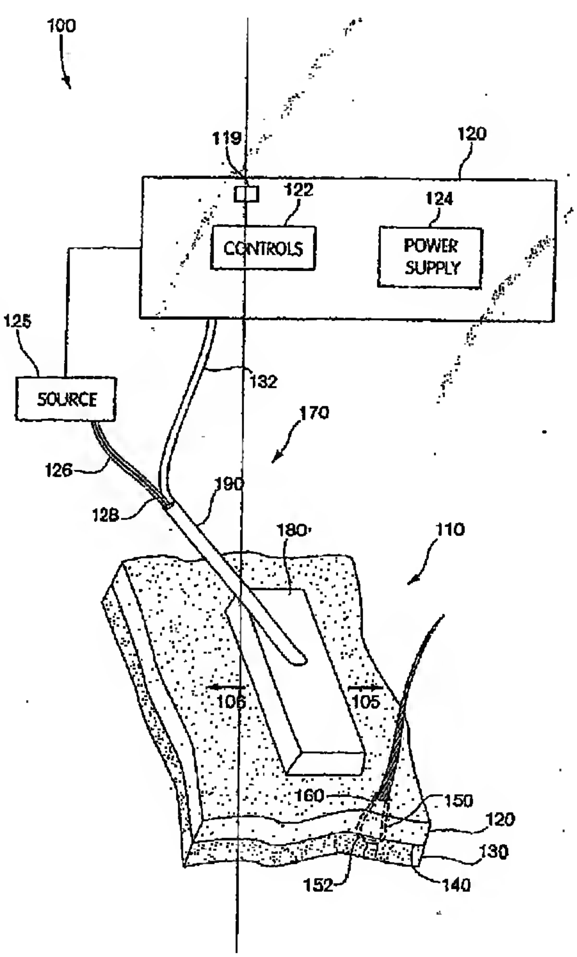
(54) Title: COOLING SYSTEM FOR A PI-IOT000SMETIC DEVICE



(57) Abstract: Photocosmetic device (100) for use in medical or non-medical erwir6iiments (e.g., a home, barbershop, or spa), which can bg.,used for a variety of tissue treatments. Radiation is deliverer to the tissues via optical systems (520 for example) desiiriid to pattern the radiation and project the radiation to a particular depth. The device has a variety of cooling systems Including phase change cooling solids and liquids to cool treated skin and the radiation sources (510 for example). Contact sensors (1712) and motion sensor (1820) may be used to enhance treatment. The device may be modular to facilitate manufacture and replacement of parts.

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CI OLING SYSTEM FOR A PHOTOCOSMETIC DEVICE .

BACKGROUND OF THE INVENTION

Related Applicati • ns

This appli ation claims priority to provisional application serial number 60/3.63798, filed March 12, 2102. This application is also a continuation-in-part of application serial number 10/052,47 , filed January 18, 2002, which application is a continuation of application serial number 09/4 73,910, filed December 28, 1999, which application claims priority to provisional applic tion serial number 60/115,447, filed January 8, 1999, claims priority from provisional applic . tion serial number 60/164,492, filed November 9, 1999, and is a continuation-in-p. of-application serial number 09/078,055, filed May 13, 1998, now U. S. Patent No. 6,273, 84, which application claims priority to provisional application serial number 60/046,5 / , filed May 15, 1997 and provisional application serial number 60/077,726, filed March 12, 1 98. This application is also a continuation-in-part of application serial nwnber 09/268,43, filled March 12, 1999, which application claims priority to provisional application serial ' umber 60/115,447, filed January 8, 1999 and provisional application serial number 60/077,7' filed January 8, 1999 and is a continuation-in-part of application serial number 08/759,036, filed December 2, 1996, now U. S. Patent No. 6,015,404, and is a continuation-in-put of application serial number 08/759,136, filed December 2, 1996, now abandoned, and is a continuation-in-part of application serial number 09/078,055, filed May 13, 1998, now U. 3. Patent No. 6,273,884, which application claims priority to provisional application serial ilumber 60/046,542, filed May 15, 1997 and provisional application serial number 60/077,726, filed March 12, 1998. This application is also a continuation-in-part of application serial lumber 09/634,981, filed August 9, 2000, which application is a continuation of application serif number 09/078,055, filed May 13, 1998, now U. S. Patent No. 6,273,884, which application claims priority to provisional application serial number 60/046,542, filed May 15, 1997 *and* provisional application serial number 60/077,726, filed March 12, 1998. This application i also a continuation-in-part of application serial number 09/847,043, filed April 30, 2001, w ich claims priority to provisional application serial number 60/200,431, filed April 28, 2000. s application also claims priority to provisional application serial number 60/292,827, filed ay 23, 2001. This application also claims priority to provisional application serial umber 60/363,871, filed March 12, 2002.The contents of all of these prior application specifications are incorporated herein by reference.

Related Art

There exists a variety of conditions treatable using photocosmetic procedures (also referred to herein as photo cosmetic treatments), including light-based (e.g., using a laser or lamp) hair removal, treatment of various skin lesions, tattoo removal, facial resurfacing, and skin rejuvenation. Currently, photocosmetic procedures are performed using professional-grade devices that cause destructive heating of target structures located in the epidermis/dermis of a patient's skin.

To date, photocosmetic procedures have been performed in a dermatologist's office, partially because of the expense of the devices used to perform the prOcedures, partially because of safety concerns related to the devices, and partially because of the need to care for optically induced wounds on the patient's skin. Such wounds may arse from damage to a patient's epidermis caused by the highpower radiation and may res in significant pain and/or risk of infection. While certain photocosmetic procedures, su as CO_2 laser facial resurfacing, will continue to be performed in the dermatologist's offi e for medical reasons (e.g., the need for post-operative wound care), there are a large numbdr of photocosmetic procedures that could be performed in a non-medical environment (e.g., home, barber shop, or spa) if the consumer could perform the procedure in a safe and effective manner. Even for procedures performed in a medical environment, reduced skin damage would reduce recovery time.

Photocosmetic devices for use in medical or non-medical environments may benefit from following characteristics . (1) The device must be safe. For ex. i pie, it is necessary to avoid eye and skin injuries. (2) Preferably the device is easy to use, th allowing an operator to achieve acceptable cosmetic results after only reading a brief training period. (3) Preferably the device is robust and rugged enough to withstand abuse. (5) Preferably the device is easy to maintain. (6) Preferably the device is manufacturable in high volume. 7) Preferably the device is available at a reasonable price. (8) Preferably the device is s ll all and easily stored, for example, in a bathroom. Currently available photocosmetic devices h • e limitations related to one or more of the above challenges.

SUMMARY OF THE INVENTION

A first aspect of the invention is a photocosmetic device for use on an area of a patient's skin comprising a treatment head for use in close proximity to the patient's skin, at least one source of electromagnetic radiation positioned within the treatment head and

configured to pro ect radiation onto the area of skin, a cooling surface thermally coupled to the at least one soure , and a mechanism to direct a phase change substance onto the cooling surface. Option ly, the phase change substance comprises a liquid. Alternatively, the phase change substan comprises a solid.

In some e bodiments of the first aspect, the surface has a texture. The texture may be a linear groove p ttern or a concentric groove pattern. Alternatively, the texture is a plurality of projections. e mechanism may be a spray jet. The mechanism may further comprise a valve coupled to spray jet, wherein the valve controls the amount of liquid projected onto the cooling surfa e. A heat sensor may be used to produce a signal indicative of the temperature of at least a portion of the area of skin, and a controller maybe be used to receive the signal from e heat sensor and control-the valve in response to the temperature.

A container may be included to hold the substance. In some embodiments, the refrigerant. For example, the refrigerant comprises tetra flouroethane. The solid may be ice or an rganic compound, or an Galin alloy.

The coo g surface may be a thermally conductive electrode providing power to the source. Alterna ely, the cooling surface may be a surface of a thermally conductive heat sink that is thermally oupled to the source. The cooling surface may have at least one channel therethrough to r ceive the phase change substance. Alternatively, the cooling surface has a plurality of ch els therethrough to receive the phase change substance, the plurality of channels aligned long the length.

A second aspect of the invention is a photocosmetic device for use on an area of a patient's skin co prising a treatment head for use in close proximity to the patient's skin, at least one electro agnetic radiation source configured to project radiation through the treatment head onto the are of skin, and a first mechanism coupled to the treatment head and configured to project a first ubstance onto the patient's skin. The electromagnetic radiation source may be positioned wi the treatment head. The device may include an optical system to transmit radiation to the ea of skin, the optical system having a surface configured to contact the patient's skin. e device may further comprise a cooling surface thermally coupled to the at least one source nd said surface; and second mechanism to project a phase change substance onto the cooling urface, wherein the first mechanism is configured to use a gas formed by the phase change of e second substance to drive the first substance onto the patient's skin. The device may r comprising a cooling surface thermally coupled to the source and said

surface, and a second mechanism configured to project a portion of 1- first substance onto the cooling surface.

The first substance may be a liquid and the portion of the first substance projected onto the skin is a gas resulting from a phase change of the first substance. tematively, the first substance is a solid and the portion of the first substance projected on' the skin is a liquid resulting from a phase change of the first substance. In yet another al rnative, the first substance is a_solid and the portion of the first substance projected ont. the skin is a gas resulting from a phase change of the first substance.

The first substance may be a liquid, and the liquid may be a lo on. Alternatively, the first substance may be.a gas, and the gas may be cooled air. The seco d substance may comprise a plurality of components. The cooling surface may be a sur ace of a thermally conductive electrode providing power to the source. The cooling surf• e may be a surface of a thermally conductive heat sink that is thermally coupled to the source. Optionally, the source is one of a diode Iaser bar, light emitting diode and lamp.

A third aspect of the invention is a device for use on an area of patient's skin comprising a treatment head for use in. close, proximity to the patient's kin, at least one electromagnetic radiation source positioned in the treatment head and ~•nfigured to project electromagnetic radiation onto the area of skin, a cooling surface the 1, lycoupled to the at least one source of electromagnetic radiation and including at least one channel therethrough, and a mechanism to project a substance onto the cooling surface, and . to the at least one channel.

The substance may be a liquid or a gas.

A fourth aspect of the invention is a device for use on an area o a patient's skin comprising at least one electromagnetic radiation source configured to Project radiation onto the area of skin, a cooling surface thermally coupled to the at least one 'ource, and a solid mass thermally coupled to the cooling surface, the solid mass changing phas - in response to heat absorbed from the cooling surface..

In some embodiments the solid mass is ice or maybe dry ice. ' e device may further comprise a mechanism to bring the solid mass into contact with the coo log surface. The device may further comprise a treatment head, wherein the source is po •'tioned within the treatment head. The source may be one of a diode laser bar, light emi g diode and lamp.

The cooling surface is a surface of a thermally conductive electrode providing power to the source or a thermally conductive heat sink that is thermally coupled to the source.

A fifth'aspect of the invention is a device for use on an area of a patient's skin comprising at least one electromagnetic radiation source configured to project electromagnetic radiation onto the area of skin, a cooling surface thermally coupled to the at least one source, a solid mass thermally coupled to the cooling surface, at least a portion of the mass becoming a liquid in response to absorption of heat from the cooling surface, and an exhaust vent configured to receive a portion of the liquid and project the portion of the liquid onto the patient's skin.

The device may er comprise a mechanism for combining the liquid with a chemical substance and ecting the liquid and chemical combination onto the patient's skin.

A sixth pect of the invention is a device for use on an area of a patient's skin comprising at le t one electromagnetic radiation source configured to project electromagnetic radiation onto th area of skin, a cooling surface thermally coupled to the at least one source, and a reaction c ber thermally coupled to the cooling surface and containing at least a first chemical compo d and a second chemical compound, the first and second chemical compounds stile ed to provide an endothermic reaction within the reaction chamber.

The cool g surface may be a surface of a thermally conductive electrode providing power to the so ce, or the cooling surface may be a surface of a thermally conductive heat sink that is the ally coupled to the source.

A seven aspect of the invention is a device for use on an area of a patient's skin comprising a tre tment head for use in close proximity to the patient's skin, at least one source of electromagne c radiation positioned in the treatment head and configured to project electromagnetic adiation onto the area of skin, and a cooling surface thermally coupled to the at least one sour e of electromagnetic radiation, the cooling surface having a channel therethrough to ow a low-boiling point liquid to flow onto a surface of the cooling surface.

The de e may further comprise a valve connected to the channel to control the evaporation of e low-boiling point liquid. The device may also further comprise a heat sensor to produ e a signal indicative of the temperature of the area of skin, and a controller to receive the sign from the heat sensor and control the valve in response to the signal. The device may hav a pressure source is coupled to the channel to control the boiling of the low-boiling point li 'd. The source is one of a laser diode bar, light emitting diode and lamp.

The eig th aspect of the invention is a device for use on an area of a patient's skin comprising a tr atment head for use in close proximity to the patient's skin, at least one

electromagnetic radiation source positioned in the treatment head and configured to project radiation onto the area of skin, a heat spreader thermally coupled to ₈e at least one source, and a cooling surface, thermally coupled to the heat spreader. The source + • y be one of a diode laser bar, light emitting diode and lamp. The cooling surface may be surface of a thermally conductive electrode providing power to the source, or may be a surfs - of a thermally conductive heat sink that is thermally coupled to the source.

A ninth aspect of the invention is a cooling system for cooling heat generating device a cooling surface thermally coupled to the heat generating device, and nozzle configured to project a high pressure liquid, the liquid forming a flowing liquid on ı,- cooling surface. The high pressure liquid may be projected such that the liquid forms a stre.iu of liquid the entire distance between the nozzle and the cooling surface. The cooling surf ce may be textured. Optionally the cooling system may further comprise a cooling chambe to redirect the liquid to the cooling surface. The cooling chamber may include sidewalls and a cover. While many of the embodiments are described with reference to performing photocos etic treatments in a non-medical environment, it is to be understood that the benefits of asp tsof this invention apply to medical devices as well as non-medical devices, and the inven on applies to either without limitation.

BRIEF DESCRIPTION OF THE DRAWINGS

Illustrative, non-limiting embodiments of the present invention be described by way of example with reference to the accompanying drawings, in which the same reference numeral is for the common elements in the various figures, and in whic

FIG. I is a schematic illustration of some basic elements of a ph•tocosmetic device according to some aspects of the present invention;

FIG. 2A is a side view of one example of a radiation system ace ıı ding to some aspects of the present invention for use m performing a photocosmetic procedur= on. an area of a patient's skin;

FIG. 2B is a schematic top view of an irradiated area of a patient' . skin taken along lines 2B — 2B' of FIG. 2A;

FIG. 3 is a side view of an example of a radiation system that is c pable of forming two areas of radiation on an area of a patient's skin;

FIG. 4 is a top view of one example of a system appropriate for f•a ıs .lion of islands of treatment;

FIG. 5 'is schematic cross-sectional side view of one embodiment of a head according to aspects of the resent invention;

FIG. 6A i a cross-sectional side view one example of one embodiment of a cooling system that uses vaporative cooling;

FIG ; 6B i ' a cross-sectional side view of another embodiment of a cooling system utilizing a coolin liquid;

FIG. 6C i ' a schematic of another embodiment of a cooling system utilizing a cooling liquid and having a cooling chamber;

FIG. 6D i • a cross-sectional side view of an embodiment a head utilizing a cooling liquid in which th- exhaust vent is separated from the port through which cooling liquid enters chamber;

FIG. 7 is cross-sectional side view of an embodiment of a cooling system having channels;

FIG. 8 is . cross-sectional side view of another embodiment of a head utilizing evaporative coolu g of a liquid;

FIG. 9 is . cross-sectional side view of an embodiment of a cooling system using a solid phase-chang material according to aspects of the present invention;

FIG. 10 is cross-sectional side view of an embodiment of a cooling system using an endothermic the 'cal reaction for cooling;

FIG. 11 is cross-sectional side view of an embodiment of a device having an exhaust vent to cool a pati nt's skin;

FIG. 12A i a side view of one example of an embodiment of a single-element optical system appropriat . for use with photocosmetic devices according to some aspects of the present invention;

FIG. 12B i a ray trace of one example of an embodiment of an optical system as illustrated in FIG. 2A;

FIG. 13A i a side view of one example of an embodiment of a two-element cylindrical optical system ap opriate for use with photocosmetic devices according to some aspects of the present invention;

FIG. 13B i a ray trace of one example of an embodiment of an optical system as illustrated in FIG. 13A;

FICA. 14A is a side view of another example of a embodiment f a two-element cylindrical optical system appropriate for use with photo cosmetic dev:i ces according to some aspects of the present invention;

FIG. 14B is a ray trace of one example of an embodiment of .. optical system as illustrated in FIG. 14A;

FIG. 15A is a side view of another example of a embodiment f a two-element cylindrical optical system appropriate for use with photocosmetic dev ces according to some aspects of the present invention;

FIG. 15B is a ray trace of one example of an embodiment of .. optical system as illustrated in FIG. 15 A;

FIG. 16A is a schematic illustration of an exemplary embo• ent of a head for performing photocosmetic procedures;

FIG. 16B is a schematic illustration of an exemplary embo limer performing photocosmetic procedures that also provides the capabili ' to perform muscle stimulation during a photocosmetic procedure;

FIG. 17A is a schematic of one example of one embodiment o f an apparatus according to some aspects of the invention, which optically determines contact between an optical element and the surface of a patient's skin;

FIG. 17B is a schematic of one example of one embodiment o f an apparatus according to some aspects of the invention, which optically determines contact between an optical element and the surface of a patient's skin;

FIG. 17C is a schematic of one example of one embodiment o an apparatus according to some aspects of the invention, which electrically determines contac t between an optical element and the surface of a patient's skin;

FIG. 18A is a cutaway side view of one embodiment of a han dpiece having a motion sensor;

FIG. 18B is a schematic of one example of an embodiment of motion sensor system;

FIG. 19 is a schematic of another example of an apparatus ha . g an optical motion sensor;

FIG. 20 is a schematic of one example of one embodiment of . handpiece illustrating some aspects of a self-contained photocosmetic device according to . e present invention;

FIG. 21 is a schematic of one example of an embodiment of a . andpiece docking station for docking a self-contained photocosmetic device;

FIG. 22 ' • a schematic of one example of one embodiment of a handpiece having a detachable head;

FIG. 23 i a schematic illustrating a modular handpiece having one or more components suita le for user-replacement;

FIG. 24 is a schematic illustrating a modular optical assembly having one or more components suita sle for user-replacement;

FIG. 25 is a schematic of one example of a photocosmetic device illustrating some aspects of the pre ent invention;

FIG. 26A s a schematic of one example of a photocosmetic head illustrating aspects of the present invent on directed to treating a curved.area of skin;

FIG. 26B s a.sohematic of one embodiment of two transmission systems of a head to treat a curved s ce;

FIG. 27 is schematic illustrating an embodiment of some aspects of handpiece 2700 according to the p esent invention; and

FIG. 28 is schematic illustration of one embodiment of a photocosmetic device according to at le .. t some aspects of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 is schematic illustration of some basic elements of a photocosmetic device 100 according to s me aspects of the present invention. Area 110 is an area of a patient's skin on which a selecte photocosmetic treatment is to be performed. Area of skin 110 has a basal layer 140 in betwe n an epidermal layer 120 and a dermal layer 130. Typically, photocosmetic treatments involve treating a target area located within epidermal layer 120 or dermal layer 130. For example, the case of hair removal, it may be desirable to heat a bulb 150 of a hair follicle 160. Alter atively, only a portion of bulb 150 may be heated, for example, the basement membr e 152 between the papilla and the follicle.

In some e odiments of the present invention, the major sub-systems of device 100 include a handpiec 170, a base unit 120 and cord 126 to couple handpiece 170 to base unit 120. Base unit 12 may include a power supply 124 to power control electronics 122 and electromagnetic ra ation (EMR) source 125. Power supply 124 can be coupled to handpiece 170 via cord 126. ord 126 is preferably lightweight and flexible. Alternatively, as described with reference to F G. 21 below, cord 126 may be omitted and base unit 120 may be used as a charging station fo a rechargeable power source (e.g., batteries or capacitors) located in

handpiece .170. In some embodiments, base unit 120 can be complet ly eliminated by including a rechargeable power source and an AC adapter in the han iece 170.

Handpiece 170 includes a treatment head 180 (also referred to simply as a head) configured to be in contact with a patient's skin, and a handle 190 th may be grasped by an operator to move head 180 in any direction across the patients skin. or example, head 180 may be pushed across the skin in a forward direction 105 or pulled ac oss the skin in a backward direction 106. Typically, during a given stroke, contact will be maintained between head 180 and the patient's skin 110 while head 180 is moved. Handp ece 170 may be mechanically driven or hand-scanned across the skin surface of area 10. Firm contact between head 180 and skin 1 10 is preferable to ensure, good thermal d. optical contact. As described in greater detail below, in some embodiments of the presen invention, head 18.0 and/or area of skin 110 are cooled by a passive or active cooling app tus to prevent damage to the head and reduce the occurrence of skin damage (e.g., wounds).

In an exemplary embodiment, source 125 is located in handpi ce 170, for example in head 180. Alternatively, source 125 is located in base unit 120 and c nnected to head 180 via an optical fiber 128. -Optical fiber 128 may extend through handle 19 , or may be otherwise connected to head 180 for the purpose of delivering light to the patie

In some embodiments, controls 122 receive information from ead 180 over lines 132, for example information relating to contact of head 180 with skin 11 the rate of movement of head 180 over the patient's skin, and/or skin temperature. Controls 1 may transmit control signals to head 180 over lines 132. Lines 132 may be part of a cable lat is also connected to head 180 through handle 190 or may be otherwise connected to the h: ad. Controls 122 may also generate outputs to control the operation of source 125 and may so receive information from the source. Controls 122 may also control a selected output devi e 119, for example an audio output device (e.g., buzzer), optical output device, a sensory ou ut device (e.g., vibrator), or other feedback control to an operator. Depending on ope ator preference, other commonly used output devices may also be used. In some embodiments, output device 119 is located within handpiece 170.

FIG. 2A is a side view of one example of an illumination *syst* m 200 according to some aspects of the present invention for use in performing a photocosmeti procedure on an area of a patient's skin 110. FIG. 2B is a schematic top view of an irradiated area of a patient's skin 110 taken along lines 2B — 2B' of FIG. 2A. In an exemplary embodiment of the invention,

system 20a, hid ding an EMR source 204, is located in the head of a photocosmetic device (e.g., head 180 FIG. 1) such that the EMR source is located proximate the skin surface 110.

Depen on the treatment to be performed, source 204 may be configured to emit at a single wavelengt , multiple wavelengths, or in a wavelength band. Source 204 may be a coherent light so ce, for example a ruby, alexandrite or other solid state laser, gas laser, diode laser bar, or othe suitable laser light source. Alternatively source 204 may be an incoherent light source for e ample, an LED, arc lamp, flashlamp, fluorescent lamp, halogen lamp, halide lamp or other sui ble lamp.

An optic system 206, comprised of a plurality of optical elements, includes a surface 207 for transmi g radiation from an EMR source 204 and for contacting the patient's skin 110. Further det s of optical system 206,-are given below with reference to FIG. 12 - 16. The phrase "opti system" is used herein to refer to a system for transmitting any type of optical radiation 'table for performing photocosmetic procedures.

In some e bodiments, source 204 has an extended dimension in the x-direction (e.g., the light source is substantially linear). One of ordinary skill would understand that a plurality of point sources ay be combined to form a substantially linear source. Additionally, relatively small ear sources may be combined to form a single, longer continuous linear source, or a longe linear source having one or more discontinuities. For example, source 204 may be a diode 1 er bar having a 1 cm long emission line and a few micron line width; optionally source 04 may include two or three bars placed in a line along the x-direction to create a 2 cm or 3 m long emission line.

Alternativ y, linear sources may be placed adjacent to one another in the y -direction to form a source h ving an increased line width. System 200 may include one or more additional sources 05, similarly or differently configured than the one or more sources 204. In embodiments h ving two sources, source 204 and source 205 may emit at the same or ranges.

In embod' ents having multiple EMR sources 204, 205, it may be desirable to activate only selec d sources for a given treatment. For example, in embodiments having sources emitting at different wavelengths, for certain applications, for example, hair removal, it may be preferable o only activate a selected one or more sources and for certain other applications, for e pie, acne treatment or skin rejuvenation, to activate a selected one or

sl While sources are discussed as emitting radiation at a wavelength, one of

ordinary shill would understand that any radiation source produces li wavelengths, accordingly a specified wavelength may be a part of a . oader range.

Radiation source 204 may be a pulsed or continuous wave (C source. For applications that require coverage of large areas such as hair removal CW diode laser bars may be preferable. A method of utilizing continuous wave (CW) ligh sources for the treatment of various dermatologic disorders is described in U. S. Patent No. 6,2 3,884 B1 entitled "Methods and Apparatus for Dermatology Treatment," to Altshuler, al., the substance of which is hereby incorporated by reference. Some aspects of that pate t teach the use of a CW light source in combination with a contact optical delivery system tha can be either hand scanned or mechanically driven across the skin surface to create a pre ise temperature rise in the targeted biological structures (i.e., using continuous contact sc. ng (CCS)).

Most commercial diode laser bars exhibit lifetimes of >5000 . ours, but application according to the present invention may only require 10-100 hour life mes. Accordingly, in some embodiments of the present invention, a source 204 may be ove driven with current to increase radiation output, thus causing the diode laser to operate at a . igher temperature, and thereby sacrificing lifetime.

Diode laser bars appropriate for use with the present inventio include diode laser bars emitting at wavelengths of 790-980 nm or other suitable wavelengths Examples of sources of diode laser bars appropriate for use with aspects of the present inven n include Coherent inc. of Santa Clara, CA, or Spectra Physics of Mountain View, CA. The ove examples of sources 204, 205 are exemplary and it should be understood that aspe is of the present invention include devices and apparatus using any appropriate EMR s urce currently available or yet-to-be-developed.

For some embodiments of the present invention, for example ose requiring either low power or for treatment of small areas of a patient's skin, LEDs may b used as light sources 204, 205. LEDs are available in a wide range of emission wavelen . Similar to the diode laser sources discussed above, multiple LEDs emitting at different wa elengths could be used in a single optical system. Typical lifetimes for LEDs are in the 50,00 -hour range; similar to laser diodes, it may be possible to overdrive an LED and sacrifice life ime to generate higher optical power. For applications that require high power density, a refl .ctive concentrator (e.g., a parabolic reflector) could be used to decrease the spot size at the s :. surface.

Broadband sources (e.g., low-power halogen lamps, arc lamps and halide lamps) are another type of light source that could be used as sources 204, 205. • e or more optical filters

240 and 242 can e used to provide a wavelength band of interest for a given application. Multiple lamps c be combined to produce high power, and, similar to the case of LEDs, a concentrator coul be used to decrease the spot size at the skin surface. In some embodiments, several different types of light sources can be incorporated into a photocosmetic device (e.g., device 100 of FIG. 1).

In some e bodiments of system 200, a beam splitter 230 splits radiation from source 204 to form a firs portion of EMR and a second portion of EMR. The first portion and second portion may be fi tered by filters 240 and 242 respectively. After filtering, the portions may have the same or ifferent wavelength ranges. The functions of the first and second portions may be the same r different. For example, the function of the second portion of EMR may be to preheat the pa ent's skin 110 inpreparation for treatment by the first portion of EMR Alternatively, bo the first portion of EMR and the second portion of EMR may provide treatment.

Referring o FIG. 2B, in some embodiments, optical system 206 (visible in FIG'. 2A) is configured to fo a first area of radiation 210 along a first axis 211 on the patient's skin. 110. First area of radi tion 210 is formed from at least a first portion of electromagnetic radiation from source 204 visible in FIG. 2A). In some embodiments, a second area of radiation 220 along a second is 221 is formed on the patient's skin 110. Second area of radiation 220 may be formed from second portion of electromagnetic radiation from the radiation source 204; alternatively sec nd area of radiation 220 may be formed from light from second radiation source 205 (visib e in FIG. 2A).

In some a pects of the present invention, the first axis 211 and second axes 221 are parallel; howeve in other embodiments, the axes 211, 221 are not parallel. System 206 may be configured to orm the first area 210 a selected distance from the second area 220, or may be configured su h that the first portion of radiation overlaps at least a part of the second portion of radiati n. Optionally, system 206 is configured to form (e.g., focus or collimate) the first portion and econd portion substantially as lines. Optical system 200 may be configured to produce one o more lines of light at the skin surface, each having a length of 1-300 mm and a width of 0.1-1 mm. Astigmatism of the beam can be in the range 0.01-0.5. The term "astigmatism" is erein defined to mean the ratio of beam width to the beam length. Also, optionally, syste 206 may be configured to form one or more additional areas of radiation along additional es (not shown) on the patient's skin 110, the additional areas of radiation

formed from corresponding additional portions of electromagnetic ra ation from the radiation source 204 or 205, or radiation from one or more additional radiation ources.

FIG. 3 is a side view of another example of an. illumination sy tem 300 for use in performing photocosmetic procedures, that is capable of forming two areas of radiation 311, 316 on an area of a patient's skin 110. In system 300, two optical syst ms 310, 315, instead of a single optical system 206 (Fig. 2), each generate a corresponding ar of radiation 311, 316 (e.g., areas of radiation 210, 220). The radiation used to generate the 1 es may be from two sources 304, 305 or a single divided source as described above with re erence to FIG. 2.

FIG. 4 is a top view of one example of an illumination system 00 appropriate for formation of islands of treatment. System 400 includes a plurality of s urces 410 (e.g., a conventional laser diode emitting a line or circular spot of illuminatio , each having a corresponding optical system 415 to direct light onto an area of skin. he illustrated system may be used to create a square (or arbitrarily shaped) matrix of focal spots having islands of treatment within the area of skin. The term "island" as used here is defined to mean an area of specified treatment separated from other areas of the specified treatment, such that areas between two or more areas receive radiation in an amount below that necessary to, achieve the specified treatment. Islands of illumination are discussed in greater detail in U.S. Provisional Patent Application 10/033,302, filed December 27, 2001, by Anderson, entitled "Method and Apparatus for EMR Treatment" the substance of which is hereby incorporated by reference.

For embodiments of photocosmetic devices according to the present invention that utilize high-power sources, management of waste heat from the sources is important for avoiding wounds and other injuries to the consumer. For example, in the case of a photocosmetic device that includes diode laser bars in the handpiece, up to 60% of the electrical energy may be dissipated in non-optical waste heat. In additicn to the removal of heat to avoid wounds, removal of heat may be important to prevent the source from overheating and shortening the lifetime of the source.

FIG. 5 is a schematic cross-sectional side view of one embodiment of a head 500 according to aspects of the present invention. Head 500 includes an illumination system including an EMR source (e.g., diode laser bar 510) and an optical system 520. Head 500 may be located in a housing to protect the optical components and to protect the operator of a photocosmetic device; the housing is omitted to avoid obfuscation. In F=G. 5, a diode laser bar 510 operates as the source of electromagnetic radiation (e.g., source 204 in FIG. 2) and may be used to form one or more areas of radiation (e.g., 210, 220 in FIG. 2). Diode laser bar 510 is

located between ositive electrode 515 and negative electrode 516. Electrodes 515, 516 provide electrical power to diode laser bar 510, and may be made of any suitable material having good elec -'cal conductivity. In some embodiments, electrodes 515, 516 are in thermal contact with diod laser bar 510, and have good thermal conductivity to transfer waste heat away from diode aser bar 510. For example, electrodes 515 and 516 may be made of aluminum or cop 'er

Optionall waste heat from diode laser bar 510 may be transferred via electrodes 515 and 516 to a heat ink 530. Heat sink 530 may be made of any material having good thermal conductivity to tr nsfer waste heat away from diode bar 510. For example, heat sink 530 may be made of alumi urn or copper. Heat sink 530 can be cooled by any appropriate, known method of coolin including a stream of air. Optionally, cooling may be enhanced by adding fins (not shown) t heat sink 530. Alternatively, heat sink 530 may be cooled by one or more of the heat remov methods discussed below with reference to FIGS. 6 11. Also optionally, a heat spreader 522 ay be located between electrodes 515, 516 and heatsink 530. Heat spreader 522 is th rurally coupled to electrodes 515, 516 and heat sink 530. Heat spreader 522 maybe made of y suitable material having good thermal conductivity; preferably heat spreader 522 is el ctrically insulative. Diamond and carbon fiber are two examples of materials suitable or use as heat spreaders.

In some e bodiments, electrodes 515, 516 are configured to be heat sinks to conduct waste heat away om diode laser bar 510. Accordingly, heat sink 530 and heat spreader 522 may be omitted. such embodiments, electrodes 515 and 516 can be made of any materially exhibiting good rmal and electrical conductivity. Optionally, one or more thermal sensors 524 (e.g. a therm ouple, a thermistor) may be used to monitor a temperature indicative of a patient's skin. (e.g , the temperature at the interface of an optical system 520 and electrode 516) for use in a coolie system as described below.

Diode lase bar 510 may be secured to electrodes 515 and 516 using any method capable of maint g good electrical contact between bar 510 and electrodes 515,516. In embodiments wh e transfer of waste heat is desired, any suitable method of achieving good thermal and electr cal contact may be used. In one embodiment, diode laser bar 510 is clamped between he two electrodes 515 and 516. A spring or other suitable device may be used to clamp dio e laser bar 510 firmly between electrodes 515, 516. In another embodiment, diode laser bar 51 may also be glued in place with thermallelectrical conductive epoxy. In another embo dim nt, diode laser bar 510 is soldered in place with a low-temperature solder (In

or Au/Sn ;older, etc.). Automated soldering may be achieved using indium preform placed between diode laser bar 510 and electrodes 515 and 516, and applyin heat using a die bonder to heat, compress, and then cool the solder and diode bar. Optionall a spacer 525, made out of a material with high thermal and low electrical conductivity such s BeO, may be included to provide electrical insulation between the electrodes 515 and 516.

According to some aspects of the present invention, optical tem 520 couples light from diode laser bar 510 to a patient's skin. Optical system. 520 may e separated from diode laser bar 510. by an air gap 511. Exemplary optical systems 520 are d scribed in greater detail below with reference to FIGs. 12 - 15. In embodiments according so e aspects of the present invention, optical system 520 is configured to. contact an area of a pat ent's skin, and the optical surface 521 is cooled to provide cooling to the patient's skin.

In some embodiments, cooling of diode laser bar 510 and opti al system 520 are achieved using a single cooling system. For example, electrodes 515, 516 may be thermally coupled to optical system 520 along dimensions A; accordingly, both 'ode laser bar 510 and optical system 520 may be cooled by cooling the electrodes 515, 516 ectly or via cooling of a heat sink 530 that is thermally coupled to electrodes 515, 516. Dim nsions A are typically both between roughly 1 and 10 mm. Further detail regarding siniultan ous cooling of an optical source and an optical system are given in U.S. application serf l number 09/4.73,910, filed December 28, 1999, the substance of which is hereby incorporat d by reference.

Contact cooling of the skin may be used to protect a patient's dpidermis during delivery ofhigh-fluence radiation to the skin, for example at wavelengths where melanin, exhibits significant absorption. In some embodiments of head 500, optical system 520 includes a sapphire element configured to contact a patient's skin due to its good optical transmissivity and thermal conductivity. As described above, optical system 520 may be cooled to remove heat from the sapphire element during treatment. Optionally, prior to treatment with the photocosmetic device, a lotion that is transparent at the operative wavelength(s) may be applied on the skin. Preferably, the location is thermally conductive to enhance heat removal from the skin through optical surface 521. Preferably, the lotion also facilitates the gliding motion of the optical system 520 over the skin surface and has a refrac-.ive index match between contact surface 520 and the skin 110 to provide efficient optical coupling of the radiation into the skin.

The lotion may also be used to show which skin areas have been treated by choosing a lotion with optical properties (e.g., color or reflectance) that are altered in response to

irradiation bran' MR source (e.g., laser diode 510). For example, if the lotion is initially a given color, after irradiation it would become transparent (or a different color). The ability to distinguish treate from untreated areas is particularly important for treatments such as hair removal that are erformed over a large surface area.

FIG. 5 als illustrates one embodiment of a system for cooling diode bar 510 and optical system 52 via heat sink 530. In FIG. 5, a heat absorbitive liquid flows through a Thermally conduc 'Ire conduit 540 that is thermally coupled to heatsink 530. For example, in one embodiment, water is used as the liquid. Optionally water may be provided by attaching a source of cold w. er, such as tap water; referring to FIG. 1, water may be provided through a handle 190 havin suitable plumbing. Alternatively, a closed-circuit cooling loop having a heat exchanger (n • t shown) to remove heat from the liquid; the heat exchanger may be located in handle .190 or • ase unit 120.

Referring gain to FIG.. 5, conduit 540 covers at least a portion of one or more surfaces, for example, surf. ce 542 of heat sink 530. A single planar conduit may cover the entirety of one or more surfa es of heat sink 530. Alternatively, a plurality of conduits, each covering a portion of a surfa• e heatsink 530, may be used. Alternatively, one or more conduits 540 may cover at least a po on of electrodes 515, 516. Since cooling maybe applied to either heat sink 530, directly to el: trodes 515, 516, a surface of a heatsink (e.g., surface 542), a surface of an electrode, or any • ther appropriate surface from which heat is to be removed shall hereinafter be referred to as a "cooling surface." While a cooling surface is illustrated as an external surface, it is to be derstood that a cooling surface may be an internal surface, such as a surface exposed t•. a conduit through a heat sink or an electrode.

FIG. 6A is a cross-sectional side view one example of one embodiment of a cooling system 600 that us s evaporative cooling. In FIG. 6, a phase change liquid is sprayed from one or more spray jets .10 and 620 onto the cooling surface 623. The liquid can be any suitable evaporative liqui • such that the liquid evaporates in response to heat absorbed from the cooling surface. t some embodiments, the liquid is a low-temperature boiling point liquid, directed on the he. t sink such that as the liquid boils in response to heat absorbed from the cooling surface 62 . In some embodiments, the liquid is tetrafluoroethane (boiling point -26°C), CO_2 (boili point -78°C) although any other suitable liquids (e.g., freon or liquid nitrogen) could als • be used. In some embodiments, the liquid is atomized by spray jets 610 and 620.

Optionally, the liquid can be contained in a container 625 loc ted in the base unit or handle. Preferably, container 625 is conveniently accessible by a use so as to be user-replaceable. A conduit 626 is used to. transport the liquid to spray jets 610 and 620. The amount of coolant flow is regulated by valve 627, which can be controlled manually or electrically using information regarding the amount of heat present in a system (e.g., system 500 of FIG. 5). For example, a sensor (e.g., sensor 524 in FIG. 5) can be used to control a feedback-controlled solenoid in valve 627. Optionally, each spray jet 610 and 620 can be a combination valve and spray jet eliminating the need for a separate valve 627.

Optionally, the cooling surface 623 from which evaporation occurs can be textured to increase the surface area from which the liquid can be evaporated. Although triangular texturing 615 of the evaporative surface is shown, any shape suitable for increasing surface area may be implemented. The illustrated triangular texturing 615 may be a part of a linear grooves pattern, a cross-sectional view of a concentric circular groove pattern or any other appropriate groove pattern. Other texturing includes a plurality of projections (e.g, semispheres, cylinders, or pyramids projecting from the cooling surface). Optionally, a collar 630 may be used to surround spray jets 610, 620 and heat sink 530 to contain the spray.

A phase change liquid may also be used to cool the electronicE 644 used to power and/or control a photocosmetic device. In particular, power field effect transistors (FETs) used to control the power of a photocosmetic device generate a large ount of heat. Conventionally, power FETs have been cooled using a relatively larg= heat sink, and a fan to remove heat. Such systems tend to be large and heavy. Cooling syst s according to the present invention provide an alternative method of cooling.

Optionally, a portion of the phase change liquid conduit 626 at provides liquid to remove heat generated by the EMR source may be configured to direc a portion of the phase change liquid to the spray jet 640. Spray jet 640 directs a portion of se phase change liquid onto a cooling surface (e.g., a surface of a heat sink 642). A heat sensor 646 (e.g., a thermistor) may be used to control the amount of liquid projected ont. cooling surface, for example, by controlling a valve 650.

FIG. 6B is a schematic of another embodiment of a cooling system 650 for use in a head utilizing a flowing, cooling liquid 605. In FIG. 6B, a high-press e liquid is maintained in a container 655 (e.g., tetrafluoroethane under 1 to 5 atmospheres of ressure) and projected through a nozzle 660 onto a cooling surface 665. The projected liquid 607 from nozzle 660 may be in the form of droplets or stream of liquid. In some embodim-i+ts, the liquid is

projected as a ttr am to overcome the poor aerodynamic properties (i.e., high drag) of droplets, thus improving heat removal properties of cooling system 650. As described above, cooling surface 6 5 may be any material that is a good conductor of heat (e.g., copper or silver). Preferabl cooling surface 665 is selected to have dimensions large enough such that the liquid 655 ev orates from surface *665* rather than drips off said surface.

Projected 'quid 607 from nozzle 660 is projected onto cooling surface 665 to form a flowing liquid 60 on cooling surface 665. Nozzle 660 and cooling surface 665 may be selected such that the liquid 607 projected from the nozzle 660 is a stream of liquid the entire distance between e nozzle 660, and upon impinging surface 665 *forms* a flowing liquid at cooling surface 6 5. Alternatively, nozzle 660 and cooling surface 665 may be selected such that the liquid 60 projected from nozzle 660 may form a spray of droplets between nozzle 660 and cooling surfa' e 665 before aggregating to form a flowing liquid at cooling surface 665. Because liquid pri ected from nozzle 660 is under high pressure, the flowing liquid on the cooling surface 6 flows across the cooling surface 665 at a relatively high speed V.

Forming a lowing liquid 605 on cooling surface 665 may be used to provide increased heat removal fro surface 665 compared to conventional cooling system in which droplets (i.e., a non-flowin liquid) are formed on cooling surface 665. For example, the improved heat removal may resul from the fact that droplets (as formed in a conventional system) are not formed in sufficie tnumber or density to achieve and maintain a selected amount of heat removal.

FIG. 6C is schematic of another embodiment of a cooling system 670 for use in a head, utilizing a c.()ling liquid 655 and having a cooling chamber 684. Head 670 has sidewalls 675 and a cover 6 0 having a port 682 for entry *of*the liquid *655* from nozzle 660. Sidewall 675 and cover 680 orm chamber 684. Port 682 may also serve as an exhaust vent for evaporated coolin liquid. As indicated by arrows 686, sidewalls 675 and cover 680 redirect the liquid 655 fro cover 680 back to the cooling surfaces 665. The sidewalls 675 are preferably selected to be thermally coupled to the cooling surface 665 such that liquid contacting the side ails 675 may remove heat from the cooling surface 665. Optionally, the side walls 675 ma be integrated with cooling surface *665* such that liquid contacting the sidewall 675 may r move heat. In some embodiments It may be preferable that cover 680 have poor thermal onductivity and poor wetting characteristics for the cooling liquid to improve the likelih od that the cooling liquid will reach the cooling surface 665. For example, in some embodime ts, cover 680 is made of a polymer or organic glass. Although chamber

684 is illustrated as having sidewalls and a cover forming an angle tharebetween, the chamber may be formed having a continuous curvature.

Because port 682 operates as an exhaust vent from evaporates liquid 655, the area S of port 682 determines the pressure maintained within chamber 684. In some embodiments, port 682 is selected to have a area S large enough to prevent back pressure that slows the speed of the liquid projected on the cooling surface 665; however, port ,682 may be selected to be small enough to allow the cover 680 to redirect a significant portion of liquid back to the cooling surface 665, and to maintain pressure in chamber 684 to keep the liquid from evaporating too quickly. For example, port area S may be approximately one hundred to two hundred times as large as the areas of nozzle 660. In some embodiments, the cooling liquid is selected to be a liquid that has an boiling temperature (i.e., evaporation temperature) of less than -26 degrees Celsius for pressures less than or equal to atmospheric pressure.

FIG. *6D is* a cross-sectional side view of an embodiment a luerhead 690 utilizing a cooling *liquid* in which the exhaust vent 692 is separated from the port *694.through which* cooling liquid enters chamber 696. Chamber 696 is bounded by a coc ling surface 688, side walls 693, and a cover 695. Cooling surface 688 is thermally coupled to source 525, and optical system 520 via coupling plates (described in greater. detail below).. A cooling liquid from nozzle 698 is projected onto textured cooling surface 688. A potion of the cooling liquid which does not contact cooling surface 688 directly is redirected by sUe walls 693. and cover 695 as indicated by arrows 686.

Optionally, cover 695 may be selected to have a resonant frequency to enhance its ability to redirect the liquid to cooling surface 688. Also, optionally a means to reduce the kinetic energy of the liquid (e.g., propeller, not shown) may be placed between the nozzle 698 and the cooling surface 688 to cool the liquid.

FIG. 7 is a cross-sectional side view of an embodiment of a he id 700 for contacting skin surface 110. Head 700 has channels 730 and 731in the electrodes 515, 516). Evaporative cooling may occur along the bottom surface of electrodes 515, 516 and along the surface of channels 730, 731, thus increasing the cooling surface area of head 70). Preferably, the location of channels 730 and 731 is proximate diode laser bar 510. In one embodiment, channels 730, 731 are located along the length of the diode laser bar 510 (i.e., along direction-x). In some embodiments, channels 730, 731 are located proximate a spray jet 610 to receive spray. Channels 730 and 731 may have a rectangular cross section or any other shape appropriate to improve cooling. For example, openings 740, 742 may 5e flared to receive spray

from spray jet 61 . As an alternative to a single channel extending along the length of the diode bar 510, a s ries of channels may be placed on one or both sides of diode laser bar 510 along the length the diode laser bar.

FIG. 8 is cross-sectional side view of another embodiment of a cooling system 800. In FIG. 8, a liqui is used to remove heat from cooling surface 823 but the liquid is not used in spray form. In th illustrated exemplary embodiment, liquid flows out of reservoir 825 into a plurality of chann ls 832 located within cooling surface 823. The length of each of the plurality of charm is 832 extends in the direction of the length of source 510. The liquid is brought into the al contact or physical contact with cooling surface 823.

Optional the liquid may be a low-boiling point liquid that evaporates in response to heat absorbed fro coaling surface 823. A-valve 833 may be used to control the liquid evaporation; whe significant cooling is desired, valve 833 is opened and a pressure less than equilibrium is app ied to the liquid to facilitate evaporation. The pressure drop causes the liquid to boil, whi h removes heat from cooling surface 823. Although channels 832 are illustrated as exte ding in a direction parallel to the length of light source 510, and the channels are illus ated as having rectangular cross sections, other shape of channels 832 aligned in one or ore in various directions are possible and are within the scope of the present aspect of the inve lion. A feedback signal can be derived from a thermal sensor (e.g., sensor 524 in FIG. 5) to ntrol a solenoid in control valve 833.

FIG. 9 is a ross-sectional side view of another exemplary embodiment of a head 900 for contacting a s urface 110. Head 900 has a cooling system having a cooling surface 923 that is brought hit physical contact with a solid mass (also referred to as a phase change solid). At least a ortion of the solid mass 834 changes phase in response to heat absorbed from cooling s Urfa e 923. The phase change may be from a solid to liquid, or a solid to a gas. In some embo dim ts, the solid has a melting temperature between approximately -IOC and +30C; however, in some applications, materials undergoing a phase change outside this range, particularly below range, may be utilized.

In some e odiments, the solid mass is conveniently located within a device handpiece (e.g. handpiece 17 in FIG. 1) so as to be user replaceable. In some embodiments, the solid mass is contained an insulating sleeve to avoid contact with user's hands, and/or to minimize melting do to expo *ure* to room temperature. In the illustrated embodiment, temperature control can be achi ved by using a manually or electrically controlled solenoid or a spring 835 to bring the solid ass in and out of contact with cooling surface 923.

n one embodiment of the phase-change cooling system,. the hase-change solid is ice. In this embodiment, a user could keep one or more frozen ice blocks *in* his/her freezer. When the user wanted to operate the photocosmetic device, a frozen ice blo k could be inserted in the device. In another embodiment, dry ice, which has a significantly lo er melting point than water, could also be used to achieve greater cooling capacity. It is t be understood that *the* ice block may contain water, *or* water with one or more additives to eat a user's skin.

In some embodiments, commercially available organic com unds (e.g., paraffin wax-based materials, fatty acids, cross, linked polyethylenes) may be used *as* phase change solids. Examples of appropriate paraffin wax materials include RT2 produced by Rubitherm GmbH. RT25.. has a melting point of 27.7°C. In other embodiments, greases having melting points in the 20-3.5°C range maybe used as the phase change *solid.* I another embodiment, Ga or a Ga alloy (e.g., Ga/In, Ga/In/Sn, or Ga/In/Sn/Zn), which is tailore to exhibit a melting point in the 15->50°C range, is used as *the* solid mass. In a Galin all y, the relatively high thermal conductivity of Ga (40.6 W/m*K) and In (81.6 W/m*K) wo d help to spread the waste heat throughout the alloy volume. A disposable phase-change oler cartridge maybe used to contain the phase-change solid; for example, the phase chang solid may be used either once and then discarded or may be rechargeable (i.e., resolidified on or more times).

FIG. 10 is an embodiment of ahead 1000 having a cooling sy em in which an endothermic chemical reactions is used for cooling. Examples of ap ropriate reactions are ammonium nitrate (NH_4NO_3) or ammonium chloride (NH_4Cl) introd ced into water causing an endothermic reaction. For example, if 200 ml of water is mixed with 200 g of ammonium nitrate, a temperature of approximately -5°C can be achieved, thus al wing absorption of a heat.

In FIG. 10, an endothermic reaction is contained within a reac on chamber 1050, and the reaction chamber is thermally coupled to cooling surface 1023. I some embodiments, reaction chamber 1050 could be coupled to the cooling surface1023 a *a* material having a good thermal conductivity. In some embodiments, the mechanism in ludes a thin membrane 1051 separating a first chamber of water and another chamber of o^{P}ium chloride. In some embodiments, membrane 1051 can be broken to initiate the reaction d the reaction chamber could be a disposable container. For example, the user could apply f ce to a flexible plastic reaction chamber to break a membrane and thereby produce a reservo of cold *liquid* prior to turning on the device. Alternatively, the membrane *may* be removed r otherwise manipulated

according to any Lown means to allow contents of the first chamber and the second chamber to interact.

FIG. 11 is a cross-sectional side view of an embodiment of a device 1100 having a conduit 1110 and an exhaust vent 1120. In FIG. 11, a liquid or gas entering exhaust vent 1120 is directed to an area of skin 1130 so as to pre or post cool the area of skin 1130 during treatment. For example, a portion of the same cooling liquid that is sprayed onto cooling surface 530 or the gas resulting from the evaporation of the liquid may enter conduit 1110 and be sprayed onto s_cin by vent 1120. The portion of liquid may be condensed evaporate or simply excess liquid. If, as described above, tap water was utilized for cooling (or an ice phase-change coder as described with reference to FIG. 9), it may be possible to divert a portion of the wafer after the water was used to cool the cooling surface 530. In some embodiments, the pressure from a gas resulting from a phase change cooling system may be used to drive a lotion onto a patient's skin. Although the illustrated embodiment illustrates diverting a portion of the cooling liquid after it is used to cool surface 530, in some embodiments a p rtion of the cooling liquid may be directly projected onto the skin without being used to coo the cooling surface 530.

Optionall one or more additives may be added to the liquid via conduit 1112 (e.g., to form a cooling lo on) prior to spraying on the skin. The additives could be stored in a cartridge (not sh in the handpiece or base unit. In some embodiments, to achieve a "shower effect," of the water exiting the heatsink could be exhausted onto the skin. As an alternative to usi g the evaporative liquid, an alternative source of gas, liquid or lotion (i.e., independent of cooling system) could be stored in a cartridge in the "handpiece or the base unit and dispense while the handpiece is moved across the skin surface.

To avoid bfuscation, the following exemplary embodiments of optical systems for use with aspects of present invention will be described with reference to a single electromagnetic r diation source; however as described above, one. or more sources may be used to form one r more areas of radiation. In the exemplary optical systems described below, each of th surfaces having optical power has optical power along a first axis (e.g., the y-axis) and zero ptical power along an axis normal to the first axis (i.e., the x-axis). That is, the lenses are cyl drical. Although the embodiments discussed below have planar or cylindrical curva es, other refractive or diffractive optical designs are within the scope of the present invention

FIq. 12A is a side view of one example of an embodiment of single element optical system 1200 appropriate for use with photocosmetic devices accordi g to some aspects of the present invention. Optical. system 1200 includes an element 1210 for transmitting light from an electromagnetic radiation source 1220 (e.g., a laser diode bar) to a atient'sskin 110. Element 1210 has an input surface 1211 and an output surface 1212 c nfigured to contact a patient's skin surface.

Source 1220 is closely coupled to input surface 1211 of the el ment1210 (e.g., 1 mm separation); close coupling enables a large fraction of light along a hi hly divergent fast-axis of a laser diode source to be transmitted to a patient's skin. In some em odiments, input surface 1211 has an antireflective (AR) coating.

As described above, element 1210 is made of a material subst tially transparent at the operative wavelength, and preferably made of a material that is therm ly conductive to remove heat from a treated skin surface (e.g., sapphire). In some emb iiments, the lateral sides 1213 of element 1210 are coated with a material reflective at the operative wavelength (e.g., copper, silver or gold). Additionally, the space 1221, between s urce 1220 and input surface 1211, may be surrounded with a reflective material to increase The strength of light incident on surface 1211.

In one embodiment, optical element 1210 is a sapphire plate (i. surfaces 1211 and 1212 are planar, and have no optical power). In another embodiment f optical system 1200, optical surface 1212 has a cylindrical curvature (as shown in Fig. 12) d•is selected to converge light incident on surface 1212. For example, in one embod' ent, surface 1212 has a radius of curvature of approximately 3mm. This system can be used to eat skin structures that require high treatment fluence. For example, the lens system of FIG. 1 can be used to target stem cells of hair follicle, sebaceous gland, infrainfimdibulum, vascul tissue, tattoos, or collagen.

In some embodiments, lateral surfaces 1213 have a length L ap roximately in the range 5- 50 mm,_and a cross-sectional width (measured in the x-direction) an height (measured in the y-direction) are selected to collect light from source 1220. For ex ple, for a source comprised of two 1 cm diode laser bars close-coupled to element 1210, the cross-sectional width is selected to be 2 cm, and the cross-sectional height is 2 cm.

As illustrated, optical element 1210 transmits a portion of light om source 1220 directly to surface 1212 with no reflections on lateral surfaces 1213 (e. ., exemplary ray 1230) and a portion of light from source 1220 is reflected from lateral surface 1213 prior to reaching

surface 1212 ~.g , exemplary ray 1232). An element, such as element 1210, that directs a portion of light m source to surface using total internal reflection is also referred herein to as a "waveguide."

Optionall , a tip reflector 1222 may be added to redirect light scattered out of the skin back into the s (referred to as photon recycling). For wavelengths in the near-IR, between 40% and 80% of ight incident on the skin surface is scattered out of the skin; as one of ordinary skill wo ld understand the amount of scattering is partially dependant on skin pigmentation. By redirecting light scattered out of the skin back toward the skin using tip reflector 1222, th effective fluence provided by system 1200 can be increased by more than a factor of two. hi ne embodiment, tip reflectors 1222 extend a total of 3 mm from the upper lateral surface an lower lateral surface ofelement 1210. In some embodiments, tip reflectors 1222 have a Copp r, gold or silver coating to reflect light back toward the skin.

A reflecti e coating may be applied to any non-transmissive surfaces of the device that are exposed to th reflected/scattered light from the skin. As one of ordinary skill in the art would understan• , the location and efficacy of these surfaces is dependent on the chosen focusing geome and placement of the light source(s). Photon recycling is discussed further in U.S. Applicati to 09/634,981, filed August 9, 2000, entitled "Heads for Dermatology Treatment," by A. tshuler, et al., and application serial number 09/268,433, filed March 12, 1999; the substance of both is hereby incorporated by reference. FIG. 12B is a ray trace of one example of an emt odiment of such an optical system 1200 having a source 1220 and an element 1210 as i lustrated in FIG. 12A.

FIG. 13 is a side view of one example of an embodiment of a two-element cylindrical optical system 13 0 appropriate for use with photocosmetic devices according to some aspects of the present inv ntion, in which a collimator 1310 is used in conjunction with element 1210. In FIG. 13, a fast 's collimator 1310 is very closely coupled to optical source 1220 (e.g., 0.09 mm). In one em diment, collimator 1310 has a length 1.5 mm, a planar input surface 1311, and an output s ace 1312 having a curvature of to collimate the output of collimator 1310. Element 1210 is 1 cated 0.lmm from output surface 1312. Collimator 1310 produces a beam of radiation that i substantially collimated in the y-dimension at output surface 1312. For example, collima or 1310 may be a lens module number S-TIH53 produced by Limo Gmbh of Doitmund, Germ y.

The collimated beam is projected onto input surface 1211 of optical element 1210. As described above, elenient 1210 may be a plate or may be weakly converging (e.g., output

surface 1212 may have a radius of curvature equal to 3 mm) to compensate for scattering in the skin. This system can be used to treat skin structures that require hig treatment fluence. For example, the lens system of FIG. 13 can be used to target stem cells o fhair follicle, sebaceous gland, infrainfundibulum, vascular, tattoo, or collagen. FIG. 13B is a ay trace of one example of an embodiment of such an optical system 1300 having a source 12 0 and a collimator 1310 and an element 1210 as illustrated in FIG. 13A.

FIG. 14A is a side view of another example of an embodiment of a two-element cylindrical optical system 1400 appropriate for use with photocosmeti devices according to some aspects of the present invention. In optical system 1400, the fast-axis collimator 1310 of FIG. 13 is used in conjunction with an element 1420 located 0.1 mm om surface 1312 of collimator 1310 to project light from source 1220. Element 1420 has input surface 1421 with a curvature of 1 mm, a planar output surface 1422, and a length o 1 mm. System 1400 focuses light at approximately 1 mm from surface 1422 (i.e., 1 mm b ow the skin surface for embodiments in which surface 1422 is configured to be in contact wit a patient's skin). In one embodiment, the heights of elements 1310 and 1420 are selected t be 1.5 mm. In some embodiments, lens 1420 is made of sapphire. This system can be used to target shallow skin structures that require high treatment fluence. For example, the lens s em of FIG. 14 can be used to target psoriasis, sebaceous glands, hair shafts, or hair stem cell . FIG. 14B is a ray trace of one example of an embodiment of such an optical system 140 having a source 1220 and a collimator 1310 and an element 1420 as illustrated in FIG. 14A.

FIG. 15A is a side view of another example of a embodiment o a. two-element cylindrical optical system 1500 appropriate for use with photocosmetic devices according to some aspects of the present invention. FIG. 15 illustrates an optical sy tem 1500 that can be used, for example, to focus the diode light deeper than the optical syste 1400 in Fig. 14. For example, optical system 1500 may focus the diode light approximately mm below the skin surface (i.e., 2 mm from surface 1522) to target deep structures *(e.g h* bulb, deeper blood vessels, subcutaneous fat) in the skin.

System 1500 is a two-element symmetrical lens system to proje t light from a source 1220. A first element 1510 is located approximately 1.4 mm from sour e 1220 and has a input surface 1511 that is planar and an output surface 1512 having curvature of 2.5 mm; accordingly, lens 1510 quasi-collimates the light from light source 152 . A second lens 1520 having an input surface 1521 with a curvature of 2.5 mm and a planar o tput surface 1522; accordingly lens 1522 focuses the quasi-collimated light 2 mm below e skin surface. In the

illustrated dmbo ent, aberrations in the optical system are balanced to achieve a substantially rm (i.e., "flat top") spatial optical intensity profile at output surface 1522. The flat top inte ity profile is substantially determined by spherical aberration in a plane transverse to the ylindrical surface 1522. In some embodiments, lenses 1510 and 1520 are made of sapphire FIG. 15B is a ray trace of one example of an embodiment of such an optical system 1500 hav g a source 1220 and an element 1510 and an element 1520 as illustrated in FIG. 15A.

FIG. 16A s a schematic illustration of an exemplary embodiment of a head 1600 for performing photo osmetic procedures. Head 1600 is illustrated without a housing to facilitate description. As d scribed above head 1600 will be moved along an area of a patient's skin, typically in direct on 1602 or direction 1604.

Head 160 includes an optical system 206 to transmit light from an EMR source 1630. Electrodes 1620 tivate an EMR source 1630. An electric insulator 1650 may be located between electrod s 1620 to prevent electrical contact between electrodes 1620. Electrodes 1620 may be tape ed to reduce the region of contact with a patient's skin.

FIG. 16B s a schematic illustration of an exemplary embodiment of a head 1650 for performing photo osmetic procedures that also provides the capability to perform muscle stimulation durin a photocosmetic procedure. Electrical muscle stimulation is a well-known physical therapy rocedure that may enhance the efficacy of some photocosmetic procedures. For example, elec 'cal muscle stimulation may be used to improve the efficacy of wrinkle treatment or cell ite treatment.

In one em!odiment, two electrodes 1610 for delivering the electrical stimulation are located on opposi a sides of optical system 206, on a portion of head 1600 that is designed to be in contact with a patient's skin during a photocosmetic treatment (i.e., during the delivery of EMR by system 2 16). One electrode 1610 contacts an area of a patient's skin prior to optical system 206 and other electrode 1610 contacts an area of skin after optical system 206.

A thermal conductive electric insulator 1615 (e.g., made of BeO or diamond or other suitable material) an be used to prevent electrical contact between electrodes 1610 which provide electrical timulation, and electrodes 1620 which activate EMR source 1630. An electric insulator 650 may be located between electrodes 1620 to prevent electrical contact between electrode 1620.

By appl g a constant (or pulsed) electrical current to a patient's skin via electrodes •1610 while the hadpiece is scanned across the skin surface, simultaneous muscle stimulation

and electromagnetic treatment can be achieved. In some embodimen electrodes may provide radio frequency (RF) current through skin. Alternatively, electrodes, 1610 may provide a DC current or a microwave field. In some embodiments, skin can be sc ed with a RF current or microwave field to selectively heat a portion of skin to be treated wi EMR radiation. Preheating skin may enable the power of the EMR source 1630 to be Decreased.

FIG. 17A is a schematic of one example of one embodiment an apparatus according to some aspects of the invention, which determines contact between optical element 1704 (e.g., element 1210 of FIG. 12) and the surface of a patient's skin 1701. To provide eye safety, in some embodiments of photocosm:etic devices, a contact sensor is ed to. enable an electromagnetic treatment source (e.g.,. source 510 of FIG. 5) to activ. to only when the device is in contact with a patient's skin. .

In FIG. 17A, an illumination source 1702 (e.g., diode laser or ED, separate from the treatment source) is mounted a few millimeters (e.g., 5 mm) away fro element 1704, and directed toward skin surface 1701. Optionally, illumination source .1 2 may be mounted to direct light toward skin surface 1701 through element 1704. Source I 02 may emit radiation at the same'wavelength as the treatment source 510 but preferably e radiation at a different wavelength than the treatment source 510. A detector 1712 is located o detect light from the illumination source that is reflected or scattered from the surface of s 1701. Optionally, a filter 1708 may be added to selectively transmit light from source 170 , and to eliminate wavelengths of light corresponding to the treatment source 510 and other extraneous wavelengths of light.

In the case of poor or no skin contact, a relatively large amoun of radiation light from source 1702 would reflect or scatter from the skin surface 1701 throng+ the optical system 1704 to detector 1712. As illustrated in FIG. 17B, when element 1740 is in good contact with the skin surface 1701, scattering and absorption in the skin would atte+uatelight from the illumination source 1702, and a relatively small amount of radiation wi uld reach detector 1712. Thus, by using an electronic means (e.g., a comparator) to meas e the output of detector 1712, and selecting an appropriate threshold, the treatment source can • e configured to activate only when the output of detector 1712 is below the threshold. Option. y, source 1702 and/or detector 1712 may be located in a base unit and one or more optical fi • ers may be used to couple light from the handpiece to the source or detector.

In another embodiment, detector 1712 detects light from the tr- .tment source to determine contact between element 1740 and.skin surface 1701. In su+h a system, light from

source 510 is s'ca ed and reflected by skin surface 1701 through element 1704 to detector 1712. A radiatio filter 1708 may selectively transmit this scattered and reflected radiation to detector 1712. this embodiment, the treatment source 510 is maintained at a low-power eye-safe mode until fi contact with the skin surface 1701 is made. When there is no or poor contact between skin surface 1701 and element 1704, the output of detector 1712 is relatively low. However, when element 1704 is in good contact with the skin surface 1701, the output of detector 1701 is r latively high. Thus, treatment source 510 would be configured to fire only when the output f detector 1712 was above a threshold level.

Altemativ ly, instead of source 1702 and detector 1712, a standard optical contact detector that is in an optical computer system mouse can be used, for example, the optical contact system in a CordLess Mouseman^{TM} produced by Logitech of Fremont, CA.

As an alte alive to the optical methods of determining contact, electrical methods can be used to detect ontact between element 1704 and a patient's skin 1701. FIG. 17C is a cross-sectional view of andpiece having two electrical contacts located in a portion of the handpiece such that when el ment 1704 is in contact with skin 1701, contacts 1720 are also in contact with skin 1701. ontact can be determined by measuring resistance (or capacitance) between the contacts. Tre tment source 510 would be activated when resistance (or capacitance) between contacts 720 was within a selected range (i.e., a range typical for skin). In another embodiment, con cts 1720 may be magnetic sensors to detect contact with skin surface 1701. In another alterna ve embodiment, contacts may be mechanical sensors to detect contact with sldn surface 170 l For example, one or more spring-loaded pins or buttons may be located such that when t element 1704 is in contact with the skin the pin or button is depressed. Multiple sensors, ins, buttons, or other mechanical sensors located around the perimeter of element 1704 co d be used to help ensure that the entire surface of element 1704 face was in good contact with skin. Alternatively, contacts 1720 can be conventional load cells to determine contact with skin surface 1701. Contacts, sensors, pins, buttons, or other mechanical sensors that allow for the measurement of resistance or capacitance may be preferred to ensure that the contact is ith skin and not with another surface, for example, a mirror or countertop.

In another embodiment, one or more temperature sensors are used to determine contact with skin surface 701. A typical skin surface temperature is in the 30-32°C range; accordingly temp rature sensors could be located near a surface of the device which contacts a patient's skin, an contact could be determined to occur when the measured temperatures were

within a selected range (e.g., 23-27°C). Alternatively, contact could e determined to have occurred when the temperature sensors measured a temperature vers s time slope indicative of contact. In still another embodiment, where lotion is to be dispensed on the skin (described above with reference to FIG. 11), skin contact could be detected by u mg a pressure sensor within spray jet 1120. The pressure sensor would measure the press e needed to eject the lotion onto the skin. Only when the handpiece was in good contact the skin would relatively high pressure be provided to dispense the lotion.

Contact sensor designs are described in greater detail in U.S. pplication 09/847,043, by Henry Zenzie, filed April 30, 2001, entitled "Contact Detecting M od and Apparatus for an Optical Radiation Handpiece," the substance of which is hereby in orporated by reference.

A handpiece is preferably_ scanned across a patient's skin wi n a specified speed-range. If the handpiece is moved too slowly (typical minimum speed 1imit would be between 5 and 25 mm/s depending on the application), the light dosage will be t o high and undesired thermal damage may result. Correspondingly, if the handpiece is mov ed too quickly (typically the maximum speed limit would be between 50 and 500 minis depen ding on the application), the light dosage will be too low to achieve treatment efficacy. Thus, y when the handpiece is scanned within this speed range does the handpiece emit electroma etic radiation for treatment. An exemplary speed range for operation of a photocosmeti hand piece for hair removal / growth delay is 10 - 500 mm/s which corresponds to the sp ed ranges with which is approximately equal to the speed which a typical razors passes over th it skin.

FIG. 1 8A is a cutaway side view of one embodiment of a hand iece 1800 having a motion sensor 1820 for determining handpiece speed. Motion sensor 820 may be used to prevent injury to skin 1810 by providing feedback control to a treatme t source (e.g., source 510 in FIG. 2), such that if the handpiece remains motionless or ifthe ovement across the skin 1810 is too slow. or too fast, the intensity of source may be decrea ed or increased, respectively, or the source may be turned off. Optionally, the treatmen source may be disabled instead of reduced in power. In one embodiment, a wheel 18 1 is positioned to make physical contact with skin 1810, such that the wheel rotates as handpie e 1800 is moved relative the skin 1810, and handpiece speed can be determined.

Handpiece 1800 may be configured to inform the operator whe the handpiece speed is inside or outside of an acceptable speed range. For example, a tactile dicator (e.g., a vibrator) could be configured to vibrate the handpiece when the handpi ce speed is inside or

outside the desire range. Alternatively, a visual indicator 1804 (e.g., an LED) or an audio indicator (e.g., a eeper) may be used to inform the operator that the handpiece speed is inside or outside the de red range. In some embodiments, multiple indicators 1806 (e.g., LEDs having different olors, or different sound indicators) may be used to inform the operator that the handpiece sp ed is either too high or too low or is within the desired range.

FIG. 18B s a schematic of one example of an embodiment of a motion sensor system having at least o e wheel 1821. Preferably a second wheel 1821 is added and located on an opposite side of ptical system 206 to ensure that the entire skin contacting surface of the optical system 2 6 moves at a rate of speed within the acceptable range to provide uniform illumination on a patient's skin.

In one e odiment, each external wheel 1821 is coupled to a corresponding auxiliary internal wheel 1 2 having perforations around its perimeter. A source 1830 projects light in the direction of a corresponding detector 1832 so that as a wheel 1821 rotates, the perforations of auxiliary whe 11822 alternately transmit and block light projected by source 1830; as a result, as handpi ce 1800 (visible in FIG. 18A) moves across a patient's skin, detectors 1832 produce a signal aving a chain of pulses.

One of or nary skill would understand that the speed of the handpiece across a patient's skin is roportional to the rate at which the pulses occur. A controller 1834 correlates the pulse rate to e handpiece speed. The above-described perforated auxiliary wheel design is similar toast dard computer system mouse design, for example, a mouse wheel in the 3 Bth Wheel Mou produced by Logitec Corporation of Fremont, CA, which is just one example of an a aratus to measure handpiece speed, many other apparatus are possible and pe of this aspect of the invention. For example, in an alternative embodiment, a s •pleelectric motor is coupled to wheel 1821 to generate a voltage that is proportional to dpiece speed.

FIG. 19 lustrates another optical apparatus 1900 having a motion sensor for determining han piece speed. In apparatus 1900, a light source 1902 (e.g. an infrared LED) is coupled into the ansmitting fiber 1904. A light detector 1910 (e.g., an inexpensive CCD camera or a dio sensor) is coupled to the end of a receiving fiber 1906. In apparatus 1900, the ends of the ansmitting fiber 1904 and receiving fiber 1906 are coupled together to form a single fiber end 909 that is in contact with the skin 1908. A portion of light projected onto skin surface 190 by transmitting fiber 1904 through fiber end 1908 is reflected or scattered from the skin ace 1908 and received by receiving fiber 1906 through fiber end 1909 and

detected bx detector 1910. Because the skin surface 1908 has a semi- eriodic structure (e.g., the distances between similar tissues such as hair follicle, vessels, gi ds are almost constant structure) detector output is modulated at a rate dependent on the han piece speed. *One* of ordinary skill would understand that handpiece speed can be calculate from the modulated detector output. Optionally, a second transmitting fiber 1905 and rec 'ving fiber 1907 coupled together through fiber end 1911 may be added, so that the first and se and transmitting fiber/ receiving fiber pairs are located on opposite sides of optical system 2 06 to ensure that the entire skin-contacting surface of optical system 206 moves across the skin with in the acceptable range to provide uniform illumination on a patient's skin.

In system 1900, each transmitting fibers 1904, 1905 is coupled to a corresponding receiving fiber 1906, *1907;* alternatively, a transmitting fiber and corr ponding receiving fiber, may contact the skin at distinct, separated points (i.e., the trans tting fiber and corresponding receiving fiber are not coupled at the skin); in such an e bodiment, the ends of the fibers contacting the skin maybe separated by any distance at whi photons scattered by tissue layers can be reliably detected. In such embodiments, the upper ound on-the fiber spacing occurs when the light coupled into receiving fiber is reduced t a point at which the amount of scattered photons generates *a* signal that is too small to be a urately detected.

Although optical apparatus for measuring handpiece speed hav been described, it should be understood that other methods of speed measurement are wt the scope of this aspect of the invention. For example, electromagnetic apparatuses that easure handpiece speed by recording the time dependence of electrical (capacitance and r istance)/magnetic properties of the skin as the handpiece is moved relative the skin. Alte rnatively spectrum or amplitude of sound emitted while an object is dragged acro s the skin surface can be measured and the resulting information used to calculate speed beca e the acoustic spectrum is dependent on speed. Another alternative is to use thermal s nsors to measure handpiece speed, by using two sensors separated by a distance along th direction in which the handpiece is moved along the skin (e.g., one before the optical system d one after). In such embodiments, a first sensor monitors the temperature of untreated skin, hich is independent of handpiece speed, and a second sensor monitors the post irradiation s temperature; the slower the handpiece speed, the higher the fluence delivered to a given ea of the skin, which results in a higher skin temperature measured by the second detector. T erefore, the speed can be calculated based on the temperature difference between the two senso rs.

An alternative system to measure handpiece speed using thermal characteristics uses a heat source (e.g. the treatment source or another means of heating an area of skin) located a selected distance om a thermal sensor along the direction in which the handpiece is moved along the skin. such embodiments, the handpiece speed can be determined from the temperature me ured by the thermal sensor. For a low handpiece speed, the heat would have sufficient time to propagate through the skin from the heat source to the thermal sensor; however, at high peed the heat would not have time to reach the thermal sensor. Thus, a high skin temperature measured by the thermal sensor would indicate low speed whereas a low skin temperature would indicate high speed.

In an alternative embodiment of a speed sensor, an optical apparatus is used to measure handpiece speed using-Doppler-shift techniques. In such a system, the wavelength of light from a probe laser is projected onto the skin and the speed is determined by shifted frequency of a reflected porion of the light.

In any of the above embodiments, a speed sensor may be used in conjunction with a contact sensor (e g., a contact sensor as described above with reference to FIGs. 17A-17C). In one embodiment of a handpiece, both contact and speed are determined by the same component. For xample, an optical-mouse-type sensor such as is used on a conventional computer optical mouse may be used to determine both contact and speed. In such a system, a CCD (or CMOS) array sensor is used to continuously image the skin surface. By tracking the speed of a partic ar set of skin features as described above, the handpiece speed can be measured and be ause the strength of the optical signal received by the array sensor increases upon contact wi the skin, contact can be determined by monitoring signal strength. Additionally, an ptical sensor such as a CCD or CMOS device may be used to detect and measure skin pi entation level or skin type based on the light that is reflected back from the skin; a treatment ay be varied according to pigmentation level or skin type.

In some bodiments of the present invention, a motion sensor is used in conjunction with a feedback op or look-up table to control the radiation source output. For example, the emitted laser po er can be increased in proportion to the handpiece speed according to a lookup table. In his way, a fixed skin temperature can be maintained at a selected depth (i.e., by maintaining a constant flux at the skin surface) despite the fact that a handpiece is moved at a range of handp ece speeds. The power used to achieve a given skin temperature at a specified depth is describe in greater detail in U.S. Pat. Application No. 09/634,981, which was incorporated by eference herein above. Alternatively, the post-treatment skin temperature may

be monitored, and a feedback loop used to, maintain substantially con^{s}tant fluence at the skin surface by varying the laser output power. Skin temperature can be monitored by using either conventional thermal sensors or a non-contact mid-infrared optical sensor. The above motion sensors are exemplary; motion sensing can be achieved by other means such as sound (e.g., using Doppler information).

Although the above embodiments were discussed with referen' e to a system monitoring handpiece speed as moved by an operator, the handpiece c. uld be mounted on a translation stage to move the handpiece at controlled, predetermined eed across the skin surface. In such an embodiment, the apparatus would be positioned re five the patient to treat a selected area of skin, and the translation stage could be moved to a s bsequent area as necessary.

FIG. 20 is a schematic of one example of one embodiment of a handpiece 2000 illustrating some aspects of a self-contained photocosmetic device. H dpiece 2000 includes an optical source 2055, a power supply 2047, an optical system 2044, cooling system 2046, and a speed and/or contact sensor 2048. The device is shown in contac with an area of skin 2043. Optical system 2044 'couples light from light source 2055 into th skin treatment area 2043.

Cooling system 2046 can be a *phase-change* cooler or any othe appropriate cooling system. In some embodiments cooling system 2046 is in good thermal contact with the heatsink 2045 (or electrodes or other cooling surface, not shown). A p wer supply 2047 (e.g., battery or capacitor) supplies electrical current to optical source 2055. ontact and/or speed sensor 2048 ensures safe and effective treatment as described herein ab ve. Although a contact and speed sensor is illustrated as a single component, it should be unde stood the contact and speed sensor may be different components and there may be multiple o each type of sensor as described above. Control electronics 2049 process data from contact/ eed sensors 2048 or other sensors (e.g., thermal sensors) and control optical source 2055 an cooling system 2046. Cooling system 2046 may be cooled prior to treatment via a thermal-co tact plate 2050. Power source 2047 may be charged via electrical contact 2051. On/off utton 2052 controls the electrical power. A housing 2053 may be used to enclose, protect, or ount one or more of the above parts.

Optionally, a hair removal device 2054 may be located to remo ve hair prior to irradiation by light from optical source 2055 to ensure that substantiall y no hair extends above the skin surface. For example, hair removal device 2054 may be a blad e razor (e.g., a safety

razor, a cartridge razor), an electric razor, a stripping device wherein the hair adheres to a surface and is pulled out as the handpiece is moved across a user's skin (e.g., a device like the Epilady^{TM} produced by Happy Lady, Inc.), an abrasive device that grinds the hair, or a chemical compound that dissolves the hair. A hair removal device may be made disposable such that the hair removal device is easily replaceable by a user. In the instance of coarse hair, a razor having on or a plurality of blades may be used; however in the instance of fine hair, an abrasive paper may be used. A body location having coarse hair initially may have fine hair after one or more photocosmetic treatments; accordingly, a blade razor may be used for the first few treatments and an abrasive paper may be used for subsequent treatments. In some embodiments, the. abrasive paper may be simply moved across the skin with a stroke of the photocosmetic device;_and in other embodiments the paper may be vibrated by a vibrating mechanism (e.g., a motor).

FIG. 21 is a schematic of one example of an embodiment of a handpiece docking station 2100 for cocking a handpiece 2000: Docking station 2100 is contained in housing 2155. Power supply 2156 charges battery/capacitor 2047 via electrical contact 2051. Cooling material 2046 is ooled by chiller 2157 (e.g., a Peltier element). For example, chiller 2157 may be used to r charge a cooling system, by condensing a phase change liquid or freezing a phase change sol d. Heatsink 2058 dissipates heat produced by chiller 2157. Heatsink 2058 may utilize gas, 1 quid, or solid (phase change) media for heat removal or may simply be <u>fins</u> that are cooled b exposure to room temperature. Umbilical 2159 contains wires to supply electrical power • the docking station from an electrical outlet and may further include tubing for water coolin of heatsink 2058. A self-contained photocosmetic device, and a handpiece docking station e described in greater detail in U.S. Application No. 60/292827, filed December 28, 20 00, by G. Altshuler et al., entitled "Method and Apparatus for EMR Treatment," the bstance of which is hereby incorporated by reference.

For some embodiments of a photocosmetic device, it is advantageous to have one or more replaceabl components. For example, in some embodiments, where the handpiece will likely be droppe or otherwise abused, it may be advantageous to make one or more optical systems remova le from the handpiece. In addition, to achieve a variety of treatments that each require different ptical sources or optical systems (e.g., treatment of pigmented lesion removal and trea ent to achieve <u>hair</u> removal), interchangeable optical components would permit the user t perform different applications with the same handpiece. Additionally, for

systems employing light sources or power sources having a limited lifetime, replacement of the light sources at the end of useful life may be desirable.

FIG. 22 is a schematic of one example of one embodiment of a handpiece 2200 having a detachable head 2210. Handpiece 2200 has a handle 2220 coupled to a head 2210. Handle 2220 may be coupled to head 2210 using any known method of fastering. Preferably head 2210 includes optical components (e.g., head 1600 of FIG. 16A) to facilitate the use of replaceable components.

FIG. 23 is a schematic of one example of an embodiment of a modular handpiece 2300 having one or more components suitable for, ease of manufacturablity and/or user-replacement. For example, handpiece 2300 facilitates assembly and/or replacement of a head assembly 2310 (including an optical system), a cooling assembly 2320, and a power assembly 2330. Preferably, modular handpiece 2300 is configured such that when assembled, head assembly 2310 contacts a mating power plug of power assembly 2330.

FIG. 24 is a schematic illustrating an optical assembly 2400 including a source 2410 (e.g., two diode-laser-bars). The source 2410 may be incorporated into a user-replaceable disposable cartridge, including electrodes 2412, heat sink 2430, optical system 2420 and coupling plates 2440. Coupling plates 2440 may be used to fasten optical system 2420, source 2410, and heat sink 2430. Preferably the fastening mechanism of source 2410 is configured to automatically align source 2410 to optical system 2420. Also preferab y, coupling plates are made of a material having a good thermal conductivity (e.g., copper) t conduct heat from the optical system 2420. To simplify alignment of source 2410 and eleme t 2420, source 2412 may be fixedly mounted to optical system 2420.

In addition to replacing the source 2410 at the end of its useable lifetime, it may also be desirable to facilitate the user-replacement of light sources 2410 for use for different cosmetic treatments without having to purchase multiple handpieces. Furthermo e, it may be desirable to facilitate user-replacement of light sources 2410 based on skin type, air type and/or on the location of the area of skin to be treated (e.g., underarm, bikini, leg, fac).

FIG. 25 is a schematic of one example of a photocosmetic devic 2500 illustrating some aspects of the present invention. Device 2500 has a head 2580 an a handle 2590. Head 2580 has a first optical system 2510 (e.g., optical system 310 in FIG. 3).to form a first area of radiation (e.g., area 311 in FIG. 3), and a second optical system 2515 (e. ., optical system 315 in FIG. 3) to form a second area of radiation (e.g., area 316 in FIG. 3) o a patient's skin. As described above with reference to FIG. 3, radiation to form the first are and the second area

may be from a s' gle divided source or two sources (sources not shown). Device 2500 also includes a motio sensor system having a wheel 2521 (e.g., corresponding to wheel 1821 of FIG. 18), and a s cond wheel 2522 (e.g., corresponding to wheel 1822 of FIG. 18) located on an opposite side f optical system 2510 to ensure that the entire skin contacting surface of the optical element 2 10 moves at a rate of speed within the acceptable range to provide substantially uni rm illumination on a patient's skin.

FIG. 26A s a schematic of one example of a photocosmetic head 2600 illustrating aspects of the pre ent invention directed to a treating curved area of skin (e.g., a jaw, back or aim). Head 2600 includes two pivoting transmission systems 2610 and 2620 for delivering electromagnetic r diation. The components of head 2600 are substantially contained within a housing 2630 an coupled to a base Unit (not shown) via cord 2640. Housing 2630 is illustrated as a it parent wire frame to facilitate description. The size of components of head 2600 may be sele ted according to the body part with which they are to be used, and multiple heads may be co ectable to cord 2640 to permit treatment of various body parts. Alternatively, ea head may have a fixed cord such that each cord can be plugged into a base unit and removed

FIG. 26B s a schematic of one embodiment of two transmission systems 2610 and 2620 of a head to treat a curved surface. Transmission systems 2610 and 2620 are illustrated without a housin to illustrate there relative positioning. FIG. 26B illustrates that transmission systems pivot in t least one rotational direction to facilitate maintenance of contact with a curved area of s . For example, transmission systems 2610 and 2620 may be mounted at an angle relative to ne another (e.g., 5 - 30 degrees) and mounted to enable rotation about axis X and X'.

FIG. 27 is a schematic illustrating an embodiment of some aspects of handpiece 2700 according to the resent invention. Handpiece 2700 includes a housing 2710 having a handle 2702 and a head 704. Handpiece 2700 includes a head assembly 2710 (including an optical system), a coolin assembly 2720, and a power assembly 2730.

FIG. 28 is a schematic illustration of one embodiment of a photocosmetic device 2800 according to at le some aspects of the present invention. Device 2800 includes a handpiece 2810, a base unit 820, a cord 2826 to couple handpiece 2810 to base unit 2820. Handpiece 2810 may be gra ed by an operator to move a head 2830 across a patient's skin (not shown). Head 2830 may any head as described herein above or any other suitable head to achieve a photocosmetic tr atment, for example, any of the treatments described below.

The following is a discussion of examples of treatments that c be achieved using apparatus and methods according the present invention; however, the eatments discussed are exemplary and are not intended to be limiting. Apparatus and metho s according the present invention are versatile and may be applied to any known or yet-to-be- eveloped treatments.

Exemplary treatment mechanisms include. absorption of light y a chromophore within a tissue responsible for the unwanted cosmetic condition or by a chro ophorein proximity to the tissue. Treatment may be achieved by limited heating of the Large tissue below temperature of irreversible damage or may be achieved by heating to ause irreversible damage (e.g., denaturation). Treatment may be achieved by direct stimulation of biological response to heat, or by induction of a cascade of phenomena such that a biological response is indirectly achieved by heat. A treatment may result from a combination of any f the above mechanisms. Optionally, cooling, DC or AC (RF) electrical current, physical vibra n or other physical stimulus I action may be applied to a treatment area or adjacent area to increase the efficacy of a treatment. A treatment may result from a single session, or multiple essions may be used to achieve a desired clinical effect.

A device according to one or more aspects of the invention ma operate in a variety of optical ranges. For example, electromagnetic radiation delivered to the skin may have wavelength within the range 380-1900 nm. The power of the light del' ered may be in the range 0.001-300 Wlcm, and exemplary scan speeds include 0.1-500 s t.. sec. The desired radiation characteristics may be achieved by any suitable LEDs, lamps and diode lasers or any other suitable light source presently available or yet-to-be developed.

Radiation-induced hair removal is a cosmetic treatment that co d be performed by apparatus and methods according to aspects of the present invention. the case of hair removal, the principal target for thermal destruction is the hair bulb an preferably the hair matrix, hair papilla or basement membrane of the bulb. For hair removal treatments, melanin, located in the hair shaft and follicle is the targeted chromophore. While the bulb contains melanin and can thus be thermally treated, the basement membrane, which provides the hair growth communication pathway between the papilla within the bulb and the matrix within the hair shaft, contains the highest concentration of melanin and may be sel actively targeted.

Wavelengths between 0.6 and 1.2 μm are typically used for hair removal. By. proper combination of power, speed, and focusing geometry, different hair related targets (e.g., bulb, matrix, basement membrane, stem cells) can be heated to the denaturation temperature while

the surrouridMg ermis remains undamaged. Since the targeted hair follicle and the epidermis both contain mel anin, a combination of epidermal contact cooling and long pulsewidth can be used to prevent e idermal damage. A more detailed explanation of hair removal is given in co-pending provisio al patent application number 60/363, 871, entitled "METHOD AND APPARATUS F R HAIR GROWTH CONTROL," by Rox Anderson, et al. filed March 12, 2002, which is h reby incorporated herein by reference.

Hair rem val is often required over large areas (e.g. back and legs), and the required power is therefo correspondingly large (on the order of 20-500 W) in order to achieve short treatment times. ent generation diode bars are capable of emitting 40-60 W at 800 nm, which makes the effective for use in some embodiments of photocosmetic device according to the present in ention.

Exempl methods of hair growth management may be achieved by combining low power irradiatio of hair follicles with light and physical extraction of hair shaft, andlor complete or non complete physical extraction of the hair follicle from the body. According to . some embodime is irradiation is achieved by irradiating a portion of the skin containing the hair follicle wi a light source emitting at a range of wavelengths absorbed by melanin or other endogeno or exogenous chromophores in the follicle. Physical extraction can be performed by m chanical, electromechanical or other suitable techniques. This treatment can be used for eith temporary hair reduction or permanent hair reduction.

Afirste emplary embodiment of a method of hair growth management according to the present inve lion includes first physically removing hair ("depilation") and then irradiating the skin as desc bed above. According to some embodiments, the hair removal can, be adjusted to rem ve mostly hair shafts from hair follicles; alternatively hair removal may be down to keratin ized zone. This depilation can be done by electromechanical depilation or waxing.

Phototre tment can be performed, for example, using one of the embodiments of photocosmentic device described above. According to these embodiments, light is absorbed by melanin in hair atrix and as a result of thermal injury hair growth is decelerated or completely arre ted.

Option ly, after depilation but before irradiation, a topical lotion can be applied to the skin (e.g., via e handpiece) in a treatment area to fill empty hair follicles corresponding to the removed hair. some embodiments, the transparent lotion is selected to have a refractive index in a rang suitable to provide a waveguide effect to direct the light to a region of the skin

to be irradiated. Preferably *the* index of refraction of the lotion is big than the index of refraction of water (i.e., approximately 1.33 depending on chemical a ditives of the water). In *some embodiments, the index of refraction of the lotion is higher th* the index of refraction of the dermis (i.e., approximately 1.4). In some embodiments, the ind x of refraction of the lotion is higher than *the* index of refraction of the inner root sheath (i. ., approximately 1.55). In embodiments where the index of refraction is greater than the inde of refraction of the inner root sheath, light incident on the surface of *the* skin can be deliv red directly to hair matrix without significant attenuation.

The effective pulse length used to irradiate the skin is given by e beam size divided by the speed of scanning of the irradiation source. For example, a 2 beam size moved at a scanning speed of 50-100 mm/s provides an effective pulse length of 2 - 60 ms. For a power density of 250 W/cm the effective fluence is 5-10 J/cm^2, which *approx*imately doubles the fluence of the light delivered by a device without the use of a high ind lotion.

In some embodiments, the pH of the lotion can be adjusted to d crease the denaturation threshold of matrix cells. In such embodiments, lower power is require to injure the hair matrix and thus provide hair growth management. Optionally, the lotio can be doped by molecules or ions or atoms with significant absorption of light emitted y the source. Due to increased absorption of light in hair follicle due to the lotion, a lower p ower irradiation source may be used to provide sufficient irradiation to heat the hair matrix.

A second exemplary embodiment of a method of hair growth m agement according to. the present invention includes first irradiating the. skin, and then physic y removing hair as described above. By first irradiating the skin, attachment of the hair sha to the follicle or the hair follicle to dermis is weakened. Consequently, mechanical or electr mechanical depilation may be more easily achieved (e.g., by using a soft waxing or electrome hanical epilator) and pain may be reduced.

Irradiation can weaken attachment of hair bulb to skin or subcut eous fat; therefore it is possible to pull out a significantly higher percentage of the hair follic from the skin compared to the depilation alone. Because the diameter of the hair bulb s close to the diameter of the outer root sheath, pulling out hair with hair bulb can pe anently destroy the entire hair follicle including stem cells. Accordingly, by first irradiating d then depilating, new hair growth can be delayed or terminated.

Treatment of cellulite is another example of a cosmetic problem apparatus and methods according to aspects of the present invention. The formation of

characteristic Cellulite dimples begins with poor blood and lymph circulation, which in turn inhibits the removal of cellular waste products. For example, unremoved dead cells in the intracellular space may leak lipid over time. Connective tissue damage and subsequent nodule formation occurs due to the continuing accumulation of toxins and cellular waste products.

The following are two exemplary treatments for cellulite, both of which aim to stimulate both blood flow and fibroblast growth. In a first exemplary treatment, localized areas of thermal damage are created using a treatment source emitting in the near-infrared spectral range (e.g., at a wavelength in the range 650 -1850 nm) in combination with an optical system designed to focus 2 10 mm beneath the skin surface. In one embodiment, light having a power density of 1 - 100 W/cm is delivered to the skin surface, and the apparatus is operated at a speed to create a temperature of 45 degrees Celsius at a distance 5 mm below the skin. Cooling may be applied to avoid or reduce damage to the epidermis to reduce wound formation. Furthar details of achieving a selected temperature a selected distance below the skin is given in U.S. Patent Application 09/634, 691, filed August 9, 2000, the substance of which was incorporated by reference herein above. The treatment may include compression of the tissue, massage of the tissue, or multipasses over the,tissue.

In a seco d exemplary treatment, a treatment source emitting near-infrared light (e.g., a light emitting di. de emitting at a wavelength in the range 700 1300nm) is used to focus the light a distance 2 — 10 mm beneath the skin surface, to elevate the dermis/subcutaneous fat temperature to a oint well below the thermal damage threshold (e.g., a temperature in the range 42 — 60 de ee Celcius). According to the second exemplary treatment, heating may increase the rate f lipolysis (i.e., fat breakdown) and cause apoptosis (i.e., programmed cell death) offat cell Optionally, a topical lipolytic cream may be used in combination with the second exempl treatment; the elevated temperature profile in the dermis/subcutaneous fat may enhance ere penetration and thus increase its efficacy. Due to very long thermal relaxation time subcutaneous fat (i.e., longer than 1 minute), multiple scanning treatments of an area can: achi ve the desired heating of the fat, while maintaining normal skin surface temperature. T above exemplary treatments may be used for fat metabolism activation and fat reduction.

Acne is other very common skin disorder that can be treated using apparatus and methods accord g to aspects of the present invention. Acne results when sebum from the sebaceous gland cannot reach the skin surface via the hair follicle, and a bacterial infection

occurs within the hair follicle. Photocosmetic treatment is an altemati e to traditional treatments (e.g., topical and oral medications).

The following are exemplary methods of treating acne accord i g to the present invention. In each of the exemplary methods, *the* actual treated area . . y be relatively small (assuming treatment of facial acne), thus a low power CW source ma be used. A first possible treatment is to selectively damage the sebaceous gland to pre ent sebum production. The sebaceous glands are located approximately 1 mm below the skin surface. By creating a focal spot at this depth and using a wavelength selectively absorbed b lipids (e.g., in proximity of 0.92, 1.2, and 1.7 μm), direct thermal destruction becom possible. For example, to cause thermal denaturation, a temperature of 45 65 degrees Celsius may be generated at approximately 1 mm below the skin surface using any of i e methods described in U.S. Patent Application 09/634, 691, filed August 9, 2000, the substan e of which was incorporated by reference herein above.

Optionally, a linear matrix of focal spots (as described above th reference to FIG. 4) may be used to create islands of damage. Although the exact position ~f the sebaceous glands may not be known, each treatment with a matrix of focal spots will res tin a certain number of sebaceous glands being damaged. Thus, by treating the area multipl: times, a significant number of sebaceous.. glands will be damaged.

An alternative treatment for acne involves heating a sebaceous and to a point below the thermal denaturation temperature (e.g., to a temperature 45 — 65 de ees Celsius) to achieve a cessation of sebum production and apoptosis (programmed ce death). Such selective treatment may take advantage of the low thermal threshold of ells responsible for sebum production relative to surrounding cells. Another alternative tre atment of acne is thermal destruction of the blood supply to the sebaceous glands (e.g., by he temperature 60 — 95 degrees Celsius).

For the above treatments of acne, the sebaceous gland may be se itized to near-infrared radiation by using compounds such as indocyanine green (ICG, bsorption near 800 nm) or methylene blue (absorption near 630 nm). Alternatively, non-the al photodynamic therapy agents such as photofrin may be used to sensitize sebaceous gl ds. In some embodiments, biochemical carriers such as monoclonal antibodies) may be used to selectively deliver these sensitization compounds directly to the sebaceo s glands.

Altliough e above procedures were described as treatments for acne, because the treatments invol damage/destruction of the sebaceous glands (and therefore reduction of sebum output), e treatments may also be used to treat excessively oily skin.

Another ght-based method of treating acne involves thermally destruction of the bacteria *(P. acne*) responsible for the characteristic inflammation associated with acne. Destruction of th bacteria may be achieved by targeting porphyrins stored in *P. A cnes* Porphyrines, suc as protoporphyrins, coproporphyrins, and Zn-protoporphyrins are synthesized by aerobic bacteria as their metabolic product. Porphyrines absorbs light in the visible spectral r gion from 400-700 nm, with strongest peak of absorption around 415 nm. By providing light the selected wavelength ranges in sufficient intensity heat resulting from absorption cause death of the bacteria. For example, the desired *effect* may be achieved using a treatment sour e emitting at a wavelength in the range 360-700 nm using an optical system designed to foc 02 —lmm beneath the skin surface and a power density of 0.01-10 W/cm at the skin surface.

Yet ano er technique for treating acne involves using light to expand the opening of an infected hair fo ~ cle to allow unimpeded sebum outflow. In one embodiment of the technique, a lotion that pre rentially accumulates in the follicle opening (e.g., lipid consistent lotion with organic non org nic dye or absorbtion particles) is applied to the skin surface. A treatment source wavelen is matched to an absorption band of the lotion. For example, in the case of ICG doped lotio. the source wavelength is 790-810 nm By using an optical system to generate a temperature of 45-100 degrees Celsius at the infundibulum/ infrainfundibulum, for example, by ge erating a fluence of at skin surface (e.g., 1-100 W/cm), the follicle opening can be expande. and sebum is allowed to flow out of the hair follicle and remodeling of infrainfundibuh m in order to prevent comedo (i.e., blackhead) formation.

Non-abl five wrinkle treatment, which is now used as an alternative to traditional ablative CO_2 l er skin resurfacing, is another cosmetic treatment that could be performed by apparatus and _ethods according to aspects of the present invention. Non-ablative wrinkle treatment is achieved by simultaneously cooling the epidermis and delivering light to the upper layer of the dermis to thermally stimulate fibroblasts to generate new collagen deposition.

In wrinkle treatment, because the primary chromophore is water, wavelengths ranging from 0.8-2 pm appropriate wavelengths of treatment radiation. Since only wrinkles on the face are typically of cosmetic concern, the treated area is typically relatively small and the required

coverage rate (cm^2/sec) is correspondingly low, and a relatively low- ewer treatment source may be used. An optical system providing sub-surface focusing in co i bination with epidermal cooling may be used to achieve the desired result. Precise control of . e upper-dermis temperature is important; if the temperature is too high, the induced t i rmal damage of the epidermis will be excessive, and if the temperature is too low, the amsunt of new collagen deposition will be minimal. A speed sensor (in the case of a manually scanned handpiece) or a mechanical drive may be used to precisely control *the* upper-dennis temperature. Alternatively, a non-contact mid-infrared thermal sensor could be used to monitor dermal temperature.

Vascular lesions (e.g. port-wine stains, rosacea, spider veins) present another cosmetic problem that could be treated by apparatus and methods according to aspects of the present invention. For treatment of vascular lesions, the target chromophore is blood in these lesions. Exemplary treatment wavelengths range from 0.4-0.6 μm for superficial vascular lesions and 0.6-1.3 for deep vascular lesions. In the case of treatment of spider veins, the relatively large size and corresponding long thermal relaxation time of the target tissue requires a large deposition of energy over a long time period to achieve thermal destruction and to preserve the epidermis. In addition, aggressive epidermal cooling (particularly for patients with darker skin type IV-VI) can be used to prevent epidermal damage. The use of CW sources is advantageous in the treatment of lesions because, similar to hair removal, part of the targeted structure (vein wall) contains little blood and must be damaged by thermal diffusion.

Pigmented lesions such as age spots can be removed by **selectively targeting the *cells*** containing melanin in these structures. These lesions are located using an optical system focusing at a depth of 100-200 μm below the skin surface and can be targeted with wavelengths in the 0.4-1.1 μm range, Since the individual melanin-bearing cells are small with a short thermal relaxation time, a shallow sub-surface focus is helpful to reach the denaturation temperature.

Elimination of *underarm* odor is another problem that *could* be treated by an apparatus and methods according to aspects of the present invention. In such a treatment, a source having a wavelength selectively absorbed by the eccrine/apocrine glands is used to thermally damage the eccrine/apocrine *glands*. Optionally, a sensitization compou4d may be used to enhance damage.

Tattoo removal is another procedure that can be achieved by apps atus and methods according to aspects of the present invention. Conventional devices for t ttoo removal include

short pulsed (110- 0 ns) Q-switched ruby, alexandrite, Nd:YAG and frequency-doubled Nd:YAG for cos etic tattoo removal. Typically, a source wavelength is selected based on the color of the tatto to be removed (e.g., a green laser is used to remove a red portion of a tattoo). Since the ink p. Iles are actually incorporated into individual cells, one embodiment of a thermal treatmen for tattoo removal cause the rupture of the cells, thereby releasing the ink.

Exemplar embodiments of apparatus according to aspects of the present invention for use in tattoo rem. val use a CW source, and an optical system selected to tightly focus radiation from a treatment ource at the depth where the cells containing the ink particles reside (e.g., 150-700 gm) to pture the ink-containing cells. Alternatively, it may also be possible to heat the cells below eir thermal denaturation point and induce apoptosis. In the case of embodiments de gned to cause apoptosis, healing may be enhanced by operating the radiation source in a quas continuous mode while the handpiece is continuously scanned across the skin surface to cr ate areas in which cells are damaged and areas of non-irradiated areas in between. In som embodiments, feedback from a speed sensor could be used to control laser emission and cre to equally spaced lines of damage independent of handpiece speed. To completely remo e the tattoo, multiple treatments would be required.

In some nventional, relatively expensive tattoo-removal apparatus, a Q-switched frequency-doubl d Nd:YAG laser emitting at 0.532 gm is combined with an (Nd:YAG) emitting at 1.064 gm , and alexandrite laser emitting at 0.755 pm; the lasers are selectively operated to targe cells containing various tattoo ink colors. Embodiments of modular apparatus accor g to aspects of the present invention, provide a relatively low-cost alternative to the above system. For example, an embodiment of the present invention may be configured to all w the use of optical sources emitting at distinct wavelengths or wavelength bands or a single source and optical components to modify the wavelength of the light generated by a s urce. In particular, to achieve a wavelength close to the 0.755 pm wavelength, a 0. 08 pm diode laser bar may be used; and a Nd:YAG crystal module could be inserted into the andpiece that would be pumped by the diode laser bar to produce a wavelength clos to the 1.064 gm wavelength; and to produce a wavelength close to the 0.532-gm wavelength, SHG crystal may be used to double the frequency of a laser diode emitting 1.064 gm wavel ngth radiation. Alternatively, a self-frequency-doubling crystal,such as Nd:YCOB may e used.

Low-intensity therapy (LIT) is another procedure that can be chieved by apparatus and methods according to aspects of the present invention. LIT may be u ed to for treatment of wounds, carpal-tunnel syndrome treatment, or to stimulate hair gro wth, or to accelerate biochemical reactions. Power densities and wavelengths (630-820) typically used for LITs may be achieved using diode lasers or LED treatment sources. Optio ally one or more of the above treatments may be used for veterinary LIT applications.

Elimination of or reduction of the prominence of stretch marks an scars are procedures that may be achieved using apparatus and methods according to aspe s of the present invention. Similar to the case of non-ablative skin resurfacing, to achi ve the above procedures, it may be possible to stimulate collagen deposition and w and <u>healing</u> by creating a thin thermally damaged layer in the upper dermis.

Removal of warts is another procedure that can be achieved using apparatus and methods according to aspects of the present invention. Wart removal may be achieved using a source producing light in the region of blood absorption (0.5-0.8 pm). This wavelength is selectively absorbed by hemoglobin, which appears to shuts off the w l 's blood supply.

Psoriasis is skin disorder that can be treated using apparatus an ' methods according to aspects of the present invention. Exemplary, embodiments of the pres nt.invention configured to treat psoriasis emit at wavelengths near 800 nm. Optionally, one or ' ore sensitization agents such as photodynamic drugs or ICG/Methylene blue may be usd. Treatment may be applied several times per week, and may be delivered in several differ- t ways including islands (or lines) of treatment. Additional application of apparatus and methods according to aspects of the present invention include facilitation of delivery of topic medications and cosmetic preparations into skin.

Having thus described the inventive concepts and a number of emplary embodiments, it will be apparent to those skilled in the art that the inve tion may be implemented in various ways, and that modifications and improvement will readily occur to such persons. Thus, the examples given are not intended to be limiting. The invention is limited only as required by the following claims and equivalents theret . The invention is limited only as required by the following claims and equivalents theret . Also, it is to be understood that the use of the terms "including," "comprising, " or "hav g" is meant to encompass the items listed thereafter and equivalents thereof as well as ditional items before, after, or in-between the items listed.

What is claimed is:

CLAIMS

a

1. A photocosmetic device for use on an area of a patient's skin comprising: a treatment head for use in close proximity to the patient's skin, at least one source of electromagnetic radiation positioned within the treatment head and configured to project radiation onto the area of skin; a cooling surface thermally coupled to the at least one source; and a mechanism to direct a phase change substance onto the coolupg surface.

2. The device of claim 1, wherein the phase change substance comprises a liquid.

3. The device of claim 1, wherein the phase change substance comprises a solid.

4. The device of claim 1, wherein the cooling surface has a textur

5. The device of claim 4, wherein the texture is a linear groove pa em.

6. The device of claim 4, wherein the texture is a concentric groov- pattern.

7. The device of claim 4, wherein the texture is a plurality of proje lions.

8. The device of claim 2, wherein the mechanism comprises a spr. y jet.

9. The device of claim 8, wherein the mechanism further comprise, a valve coupled to the spray jet, wherein the valve controls the amount of liquid projected into the cooling surface.

10. The device of claim 9 further comprising a heat sensor to produc a signal indicative of the temperature of at least a portion of the area of skin, and a controller t receive the signal from the heat sensor and control the valve in response to the temperature

11. The device of claim 1 further comprising a container to hold the ubstance, the container coupled to the mechanism.

a

12. The devi e of claim 2, wherein the liquid comprises a refrigerant.

13. The devi. of claim 12, wherein the refrigerant comprises tetra flouroethane.

14. The devi ~ e of claim 3, wherein the solid comprises ice.

15. The devi e of claim 3, wherein the solid comprises an organic compound.

16. The devi e of claim 3, wherein the solid is an Galin alloy.

17. The devi e of claim 1, wherein the cooling surface is a surface of a thermally conductive elec i ode providing power to the source.

18. The devi e of claim 1, wherein the cooling surface is a surface of a thermally conductive heat • ink that is thermally coupled to the source.

19. The de e of claim 2, wherein the at least one source has a length, and the cooling surface has at le: t one channel therethrough to receive the phase change substance.

20. The de ce of claim 2, wherein the at least one source has a length, and the cooling surface has a pl ality of channels therethrough to receive the phase change substance, the plurality of ch els aligned along the length.

21. A photo osmetic device for use on an area of a patient's skin comprising:

a treatm nt head for use in close proximity to the patient's skin;

at least one electromagnetic radiation source located within the treatment head configured to p oject radiation through the treatment head onto the area of skin; and

a first i echanism coupled to the treatment head and configured to project a first substance onto e patient's skin.

22. The d vice of claim 21, further comprising, an optical system to transmit radiation to the area of ski4, the optical system having a surface configured to contact the patient's skin.

23. The device of claim 21, further comprising a cooling surface thermally coupled to the at least one source and said surface, and a second mechanism to project a phase change substance onto the cooling surface, wherein the first mechanism is configured to use a gas formed by the phase change of the phase change substance to drive the) first substance onto the patient's skin.

24. The device of claim 21, further comprising a cooling surface thermally coupled to the source and said surface, and a second mechanism configured to project a first portion of the first substance onto the cooling surface._

25. The device of claim 24, wherein the first substance is a liquid d a second portion of the first substance projected onto the skin is a gas resulting from a phas change of the first substance.

26. The device of claim 24, wherein the first substance is, a solid an a second portion of the first substance projected onto the skin is a liquid resulting from a ph e change of the first substance.

27. The device of claim 24, wherein the first substance is a solid and a second portion of the first substance projected onto the skin is a gas resulting from a phase change of the first substance.

28. The device of claim 21, wherein the first substance comprises a liquid.

29. The device of claim 28, wherein the liquid comprises a lotion.

30. The device of claim 21, wherein the first substance comprises a gas.

31. The device of claim 30, wherein the gas comprises cooled air.

32. The device of claim 21, wherein the first substance comprises a pl ality of components.

33. The devic ?, of claim 23, wherein the cooling surface is a surface of a thermally conductive electrode providing power to the source.

34. The devic 5 of claim 23, wherein the cooling surface is a surface of a thermally conductive heat sink that is thermally coupled to the source.

35. The devic 3 of claim 21, wherein the source is one of a diode laser bar, light emitting diode and lamp.

36. A device for use on all area of a patient's skin comprising:

a treatment head for use in close proximity to the patient's skin;

at least one electromagnetic radiation source positioned in the treatment head and configured to project electromagnetic radiation onto the area of skin;

a cooling surface thermally coupled to the at least one source of electromagnetic radiation and inc ding at least one channel therethrough; and

a mechanism to project a substance onto the cooling surface, and into the at least one channel.

37. The devic- of claim 36, wherein the substance is a liquid.

38. The devi of claim 36, wherein the substance is a gas.

39. A device or use on an area of a patient's skin comprising:

at least o e electromagnetic radiation source configured to project radiation onto the area of skin;

a cooling urface thermally coupled to the at least one source; and

a solid m ss thermally coupled to the cooling surface, the solid mass changing phase in response to heat bsorbed from the cooling surface.

40. The device of claim 39, wherein the solid mass is ice.

41. The devi a of claim 39, wherein the solid mass is dry ice.

42.. The device of claim 39 further comprising a mechanism to bri the solid mass into contact with the cooling surface.

43. The device of claim 39 further comprising a treatment head, wherein the source is positioned within the treatment head.

44. The device of claim 39, wherein the source is one of a diode laser bar, light emitting diode and lamp.

45. The device of claim 39,..wherein the cooling surface is a surfac of a thermally conductive electrode providing power to the source.

46. The device of claim 39, wherein the cooling surface is a surfac of a thermally conductive heat, sink that is thermally coupled to the source.

47. A device for use on an area of a patient's skin comprising:

at least one electromagnetic radiation source configured to projct electromagnetic radiation onto the area of skin;

a cooling surface thermally coupled to the at least one source;

a solid mass thermally coupled to the cooling surface, at least a ortion of the mass becoming a liquid in response to absorption of heat from the cooling su ace; and

an exhaust vent configured to receive a portion of the liquid and ' roject the portion of the liquid onto 'the patient's skin.

48. The device of claim 48, further comprising a mechanism for coMbining the liquid with a chemical substance and directing the liquid and chemical combination onto the patient's skin.

49. A device for use on an area of a patient's skin comprising:

at least one electromagnetic radiation source configured to project electromagnetic radiation onto the area of skin;

a cooling surface thermally coupled to the at least one source;

a reaction chamber thermally coupled to the cooling surface and containing at least a first chemical cor ipound and a second chemical compound, the first and second chemical compounds selec ed to provide an endothermic reaction within the reaction chamber.

50. The devic of claim 49, wherein the cooling surface is a surface of a thermally conductive elect de providing power to the source.

51. The devi of claim 49, wherein the cooling surface is a surface of a thermally conductive heat s k that is thermally coupled to the source.

52. A device or use on an area of a patient's skin comprising:

a treatme t head for use in close proximity to the patient's skin;

at least o e source of electromagnetic radiation positioned in the treatment head and configured to pr ect electromagnetic radiation onto the area of skin; and

a cooling urface thermally coupled to the at least one source of electromagnetic radiation, the cooling surface having a channel therethrough to allow a low-boiling point liquid to flow onto a surface of the cooling surface.

53. The devi of claim 52 further comprising a valve connected to the channel to control the evaporation o the low-boiling point liquid.

54. The device of claim 53 further comprising a heat sensor to produce a signal indicative of the temperature of the area of skin, and a controller to receive the signal from the heat sensor and control the valve in response to the signal.

55. The device of claim 52 wherein a pressure source is coupled to the channel to control the boiling of the low-boiling point liquid.

56. The device of claim 52 wherein the source is one of a laser diode bar, light emitting diode and lamp.

57. A device or use on an area of a patient's skin comprising:

a treatme it head for use in close proximity to the patient's skin;

al least one electromagnetic radiation source positioned in the treatment head and configured to project radiation onto the area of skin;

a heat spreader thermally coupled to the at least one source; avid

a cooling surface thermally coupled to the heat spreader.

58. The applicator of claim 57, wherein the source is one of a diod- laser bar, light emitting diode and lamp.

59. The device of claim 57, wherein the cooling surface is a surfac of a,thermally conductive electrode providing power to the source.

60. The device of claim 57, wherein the cooling surface is a surface of a thermally conductive heat sink that is thermally coupled to the source.

61. A cooling system for cooling a heat generating device:

a cooling surface thermally coupled to the heat generating devi ' e;

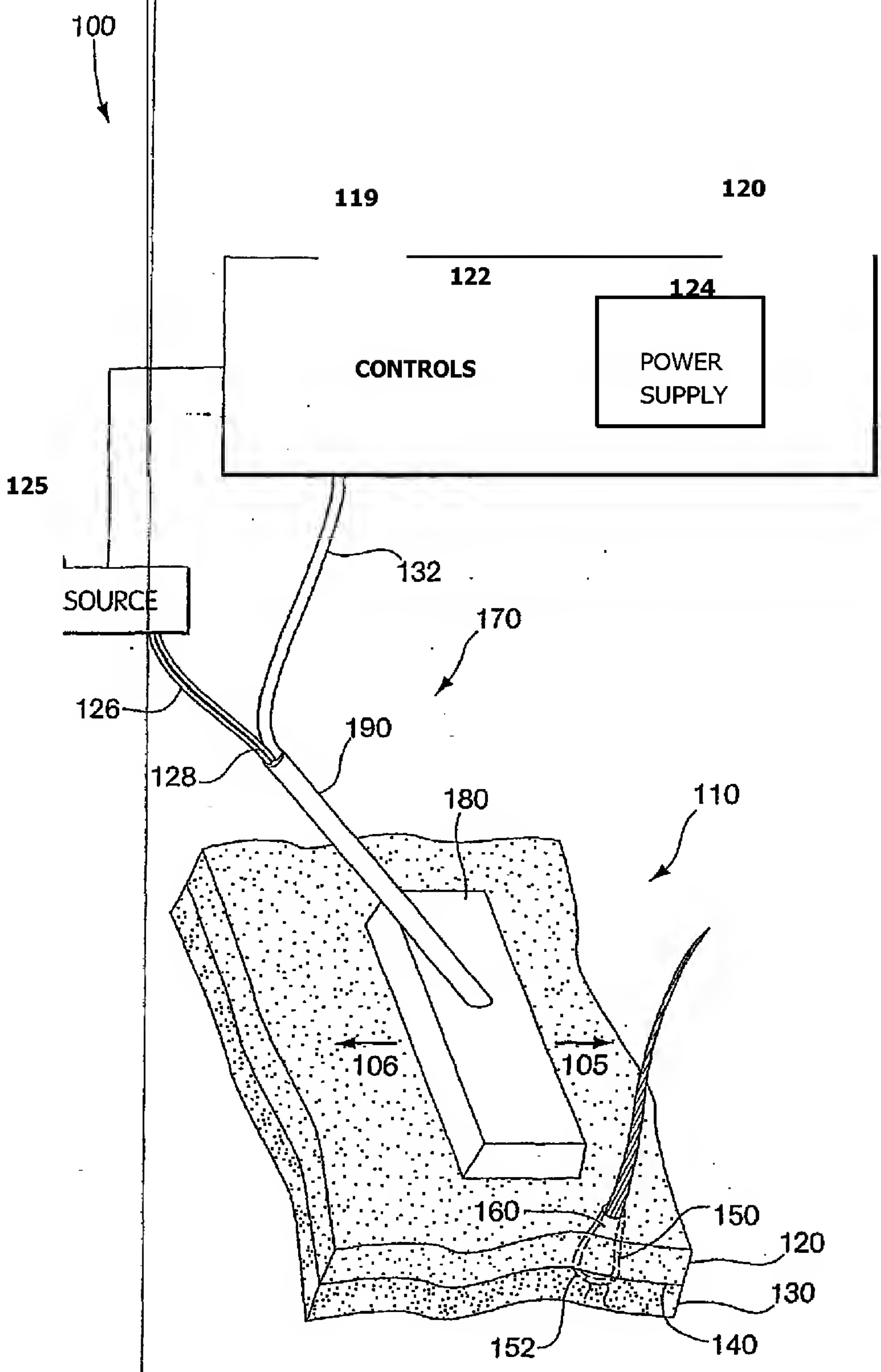
a nozzle configured to project a high pressure liquid, the liquid orming a flowing liquid on the cooling surface.

62. The cooling system of claim 61, wherein the high pressure liqui• forms a stream the entire distance between the nozzle and the cooling surface.

63. The cooling system of claim 61, wherein the cooling surface is ▪xtured. .

64. The cooling system of claim 61 further comprising a cooling ch ber to redirect the liquid to the cooling surface.

65. The cooling system of claim 64 wherein the cooling chamber in4 Ludes sidewalls and a cover.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CONTROLS
POWER SUPPLY
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Fig. 1

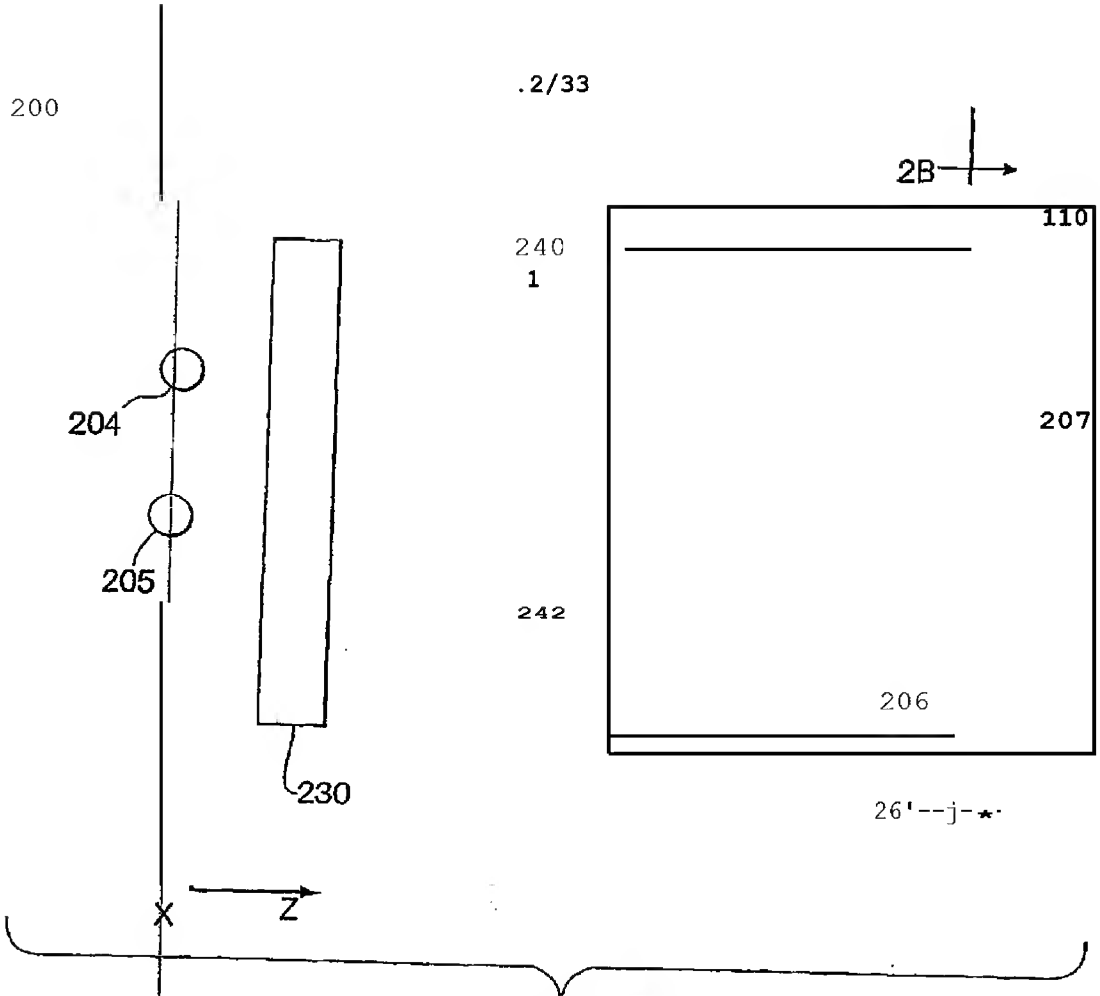
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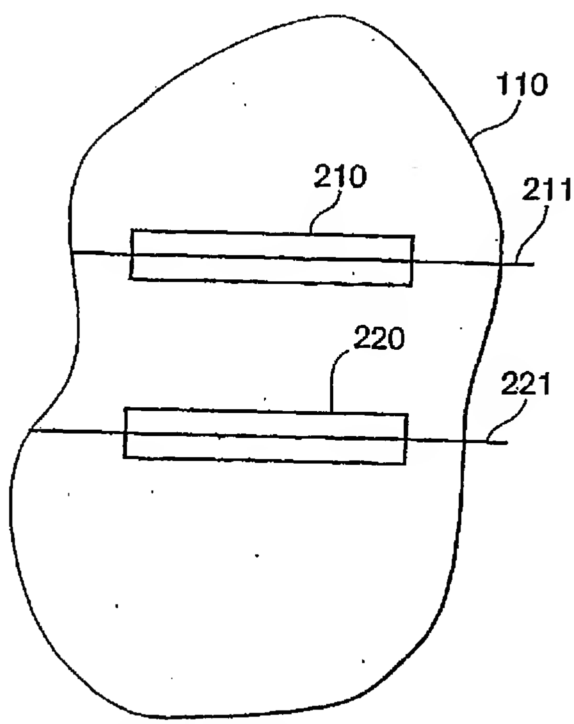
Fig. 2A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221

Fig. 2B

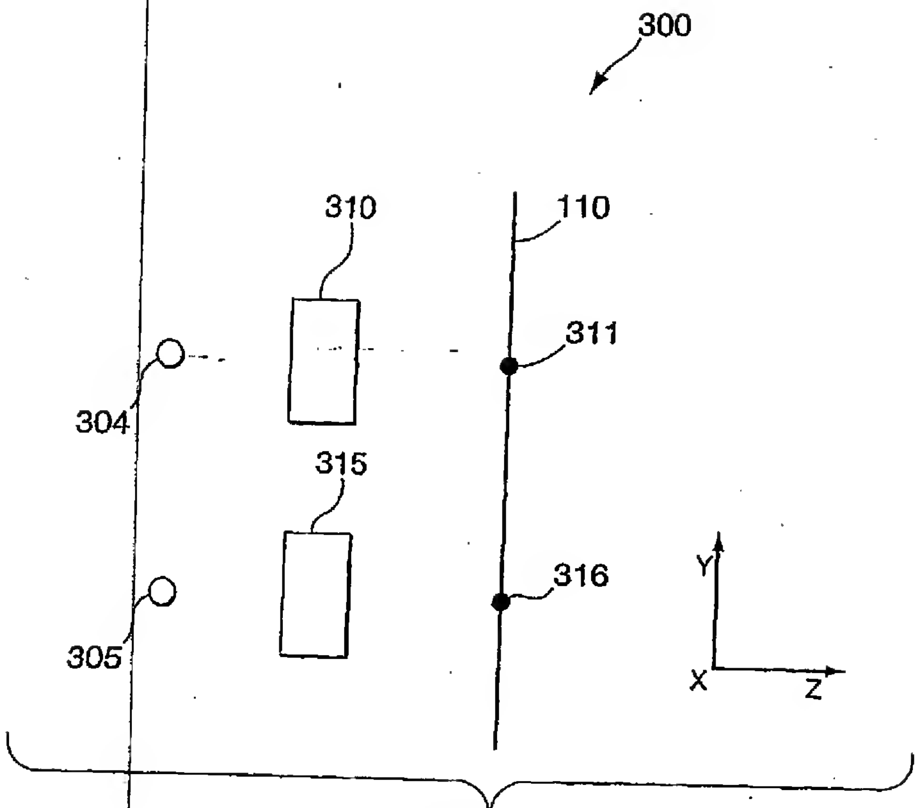

Fig. 3

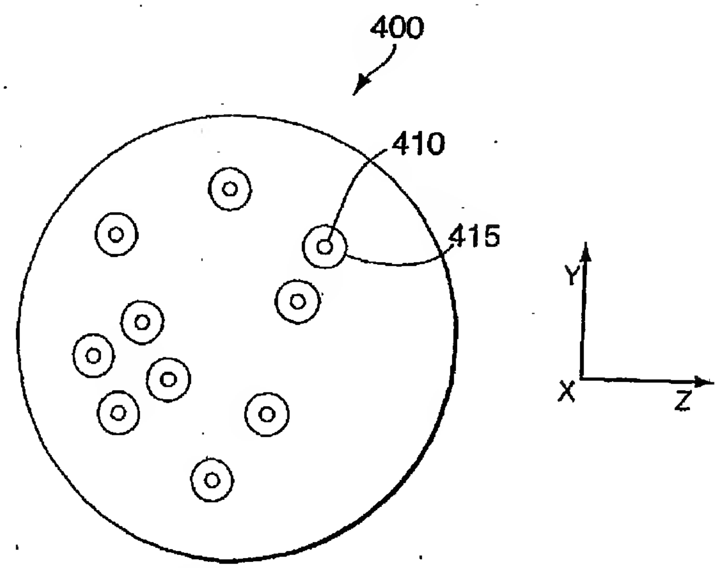

Fig. 4

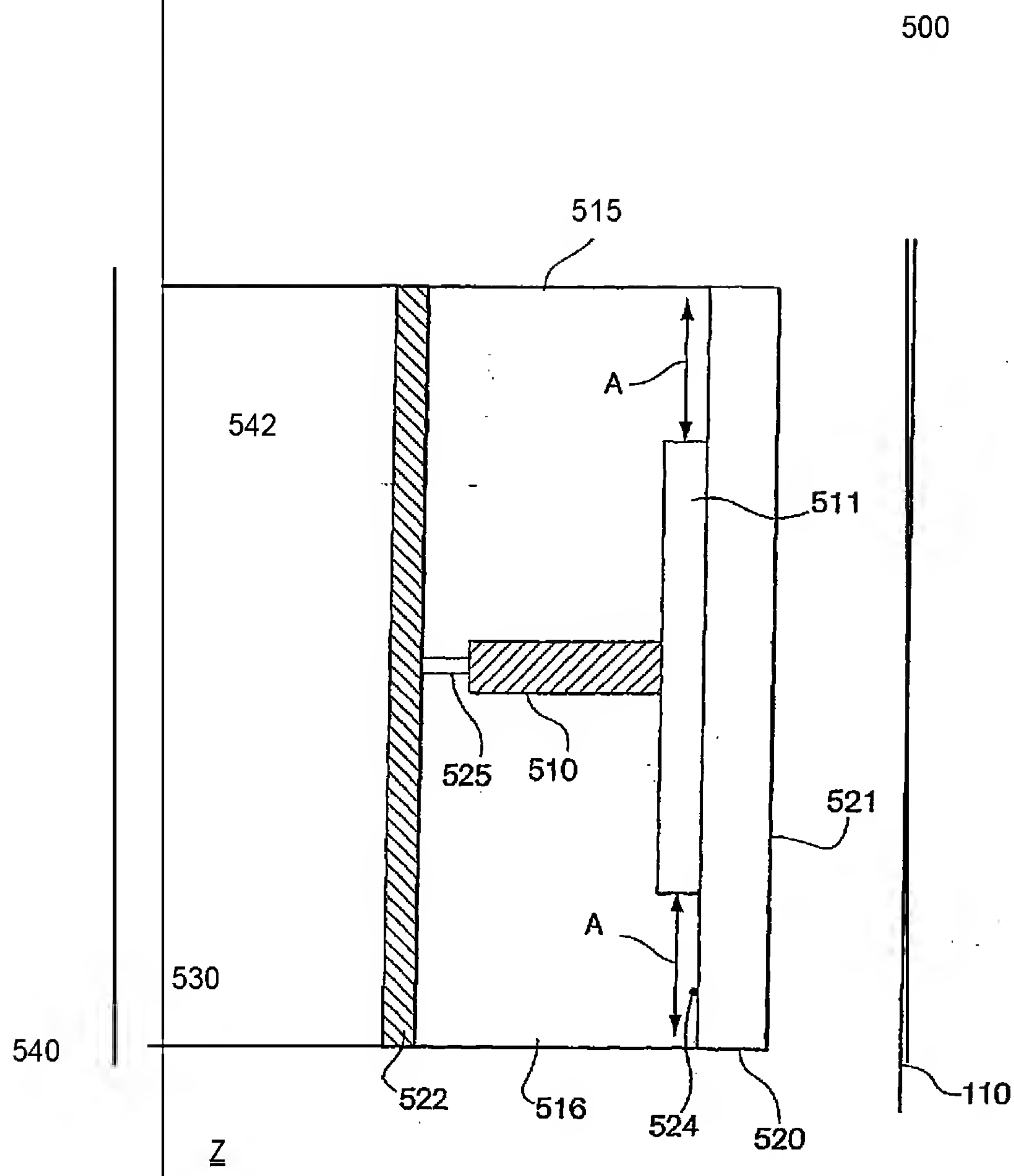

Fig. 5

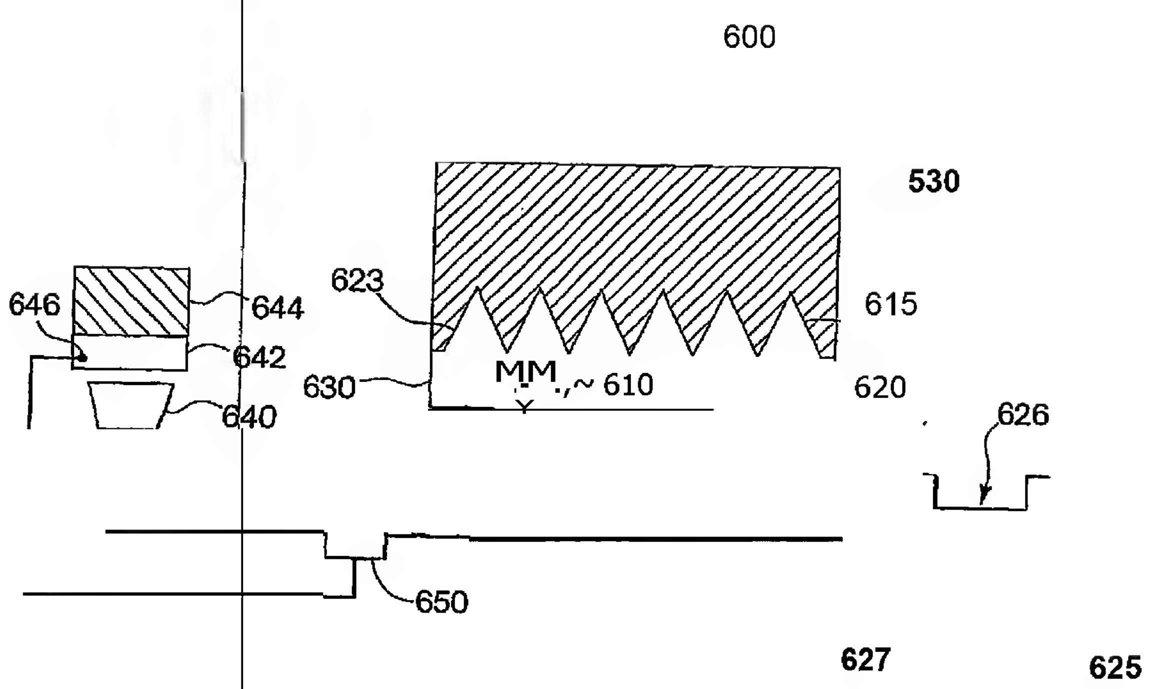

Fig. 6A

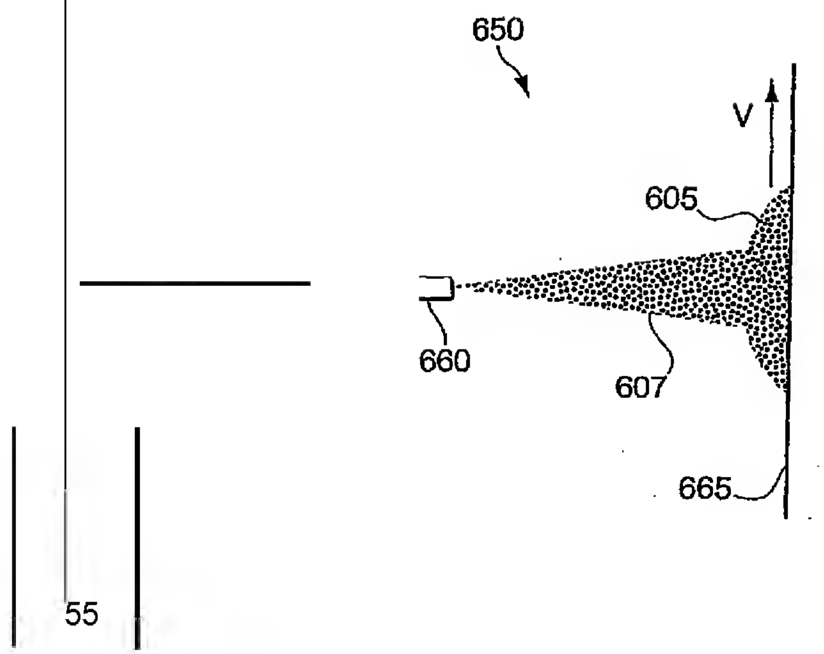
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Fig. 6B

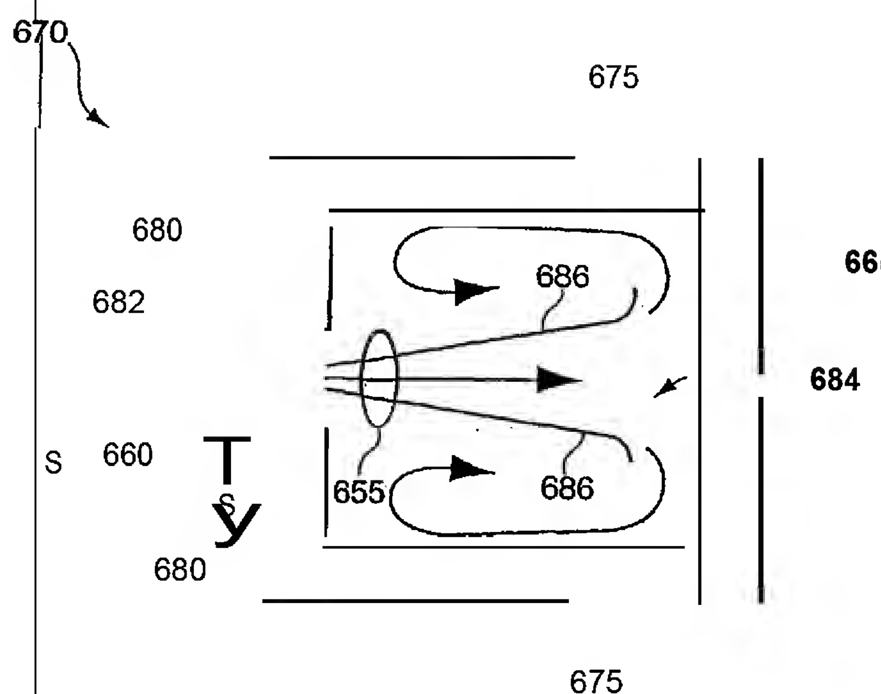
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Fig. 6C

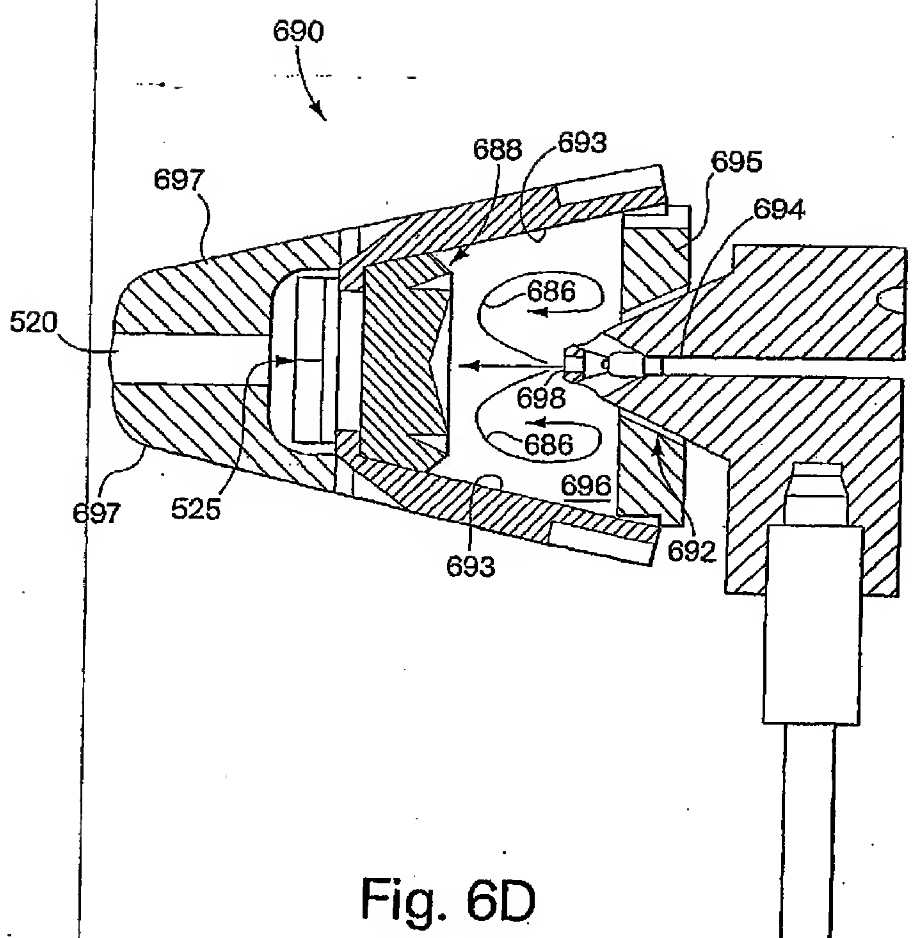


Fig. 6D

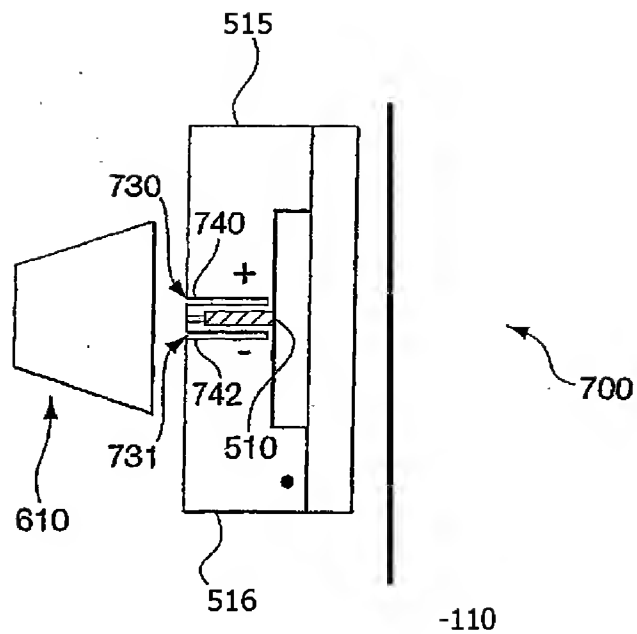


Fig. 7

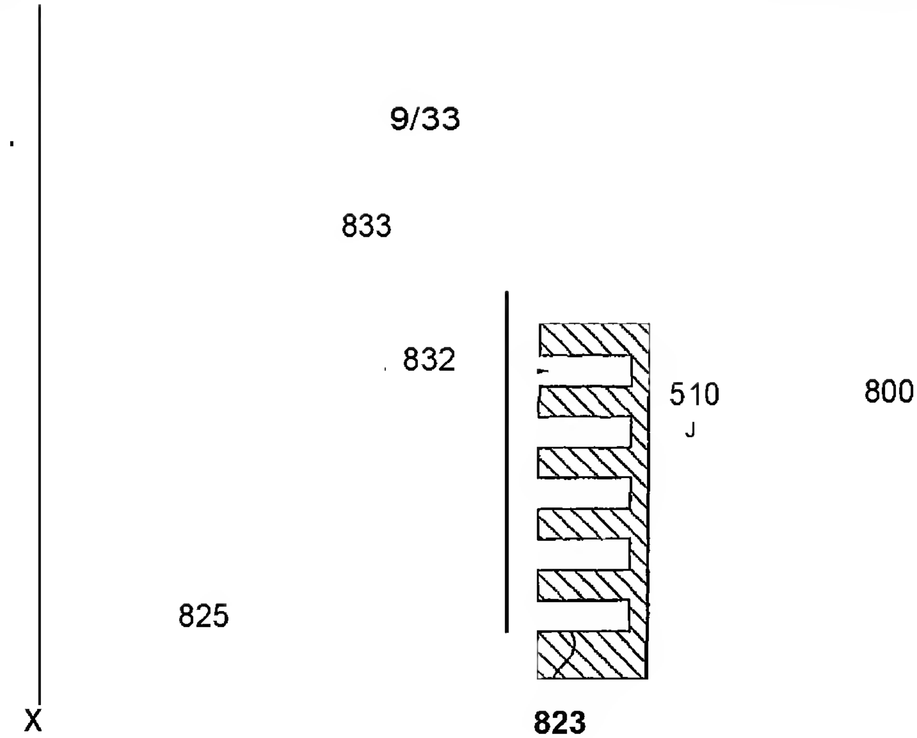
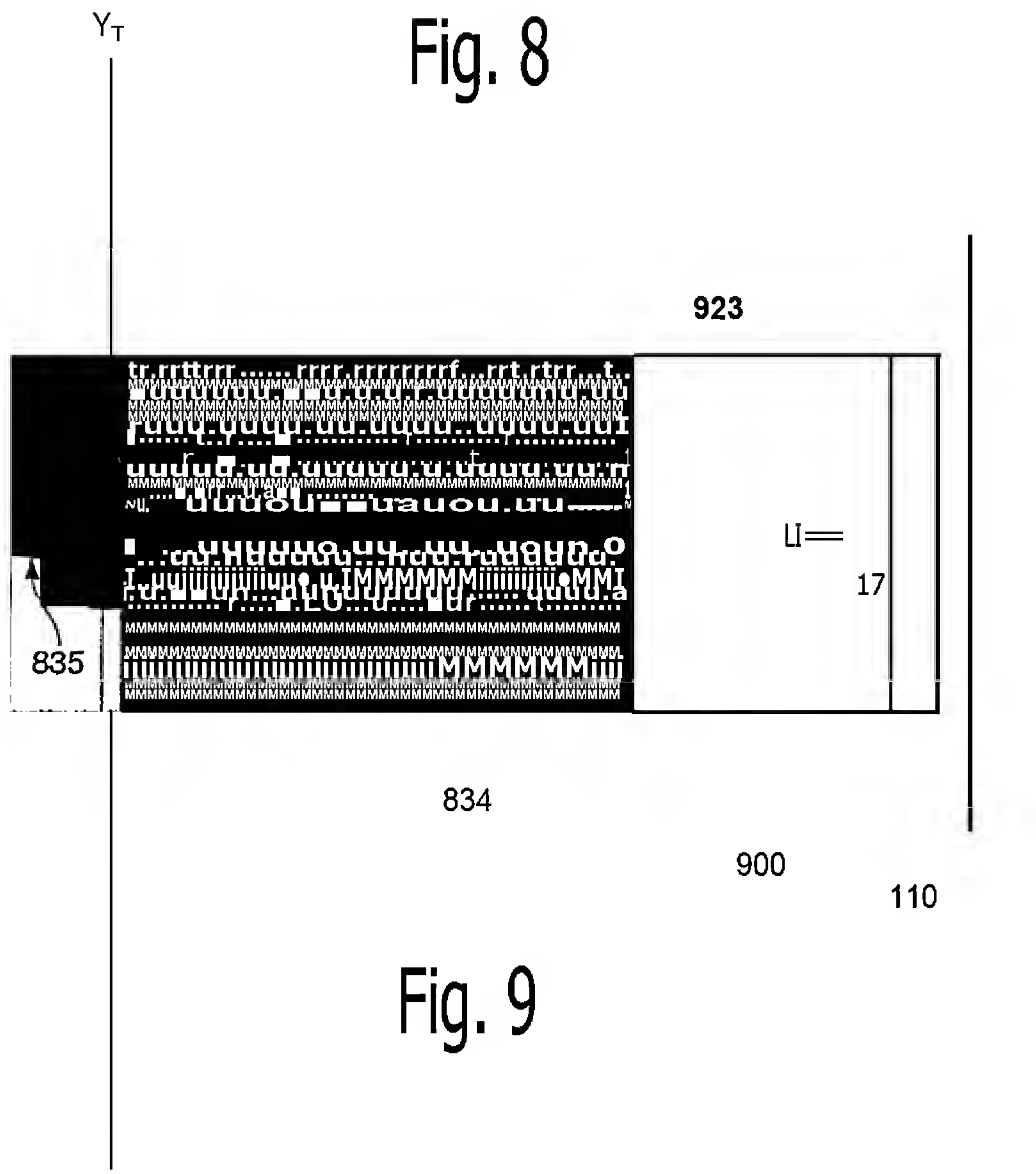


Fig. 8



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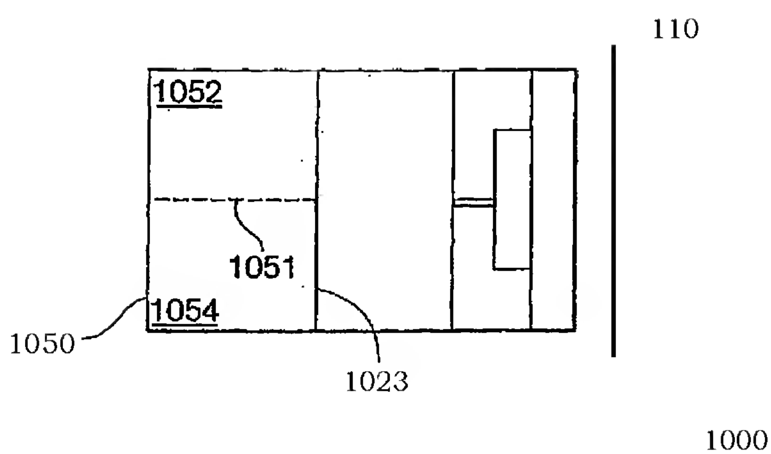

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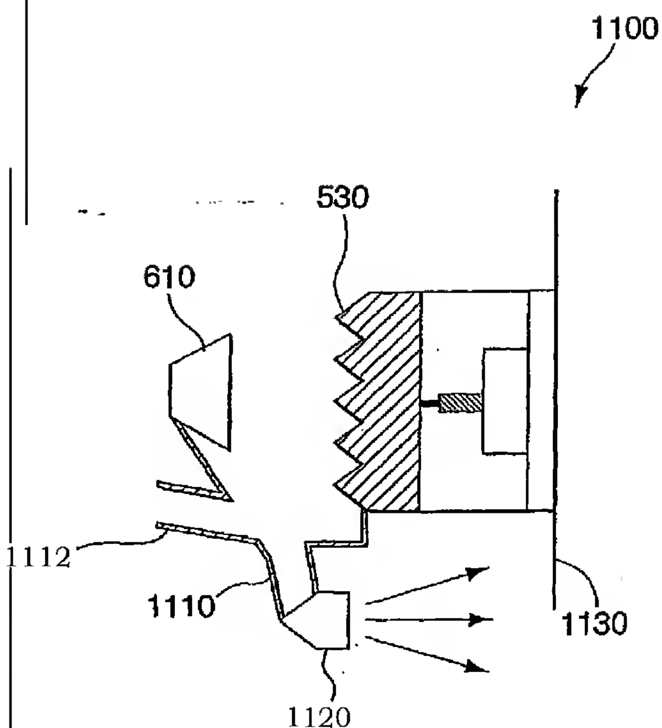

Fig. 11

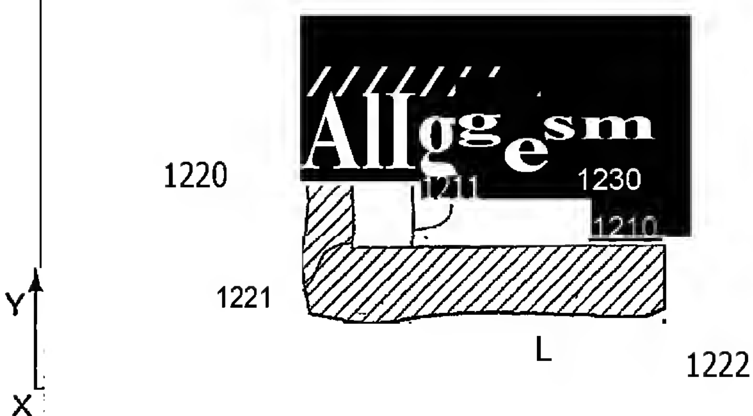

Fig. 12A

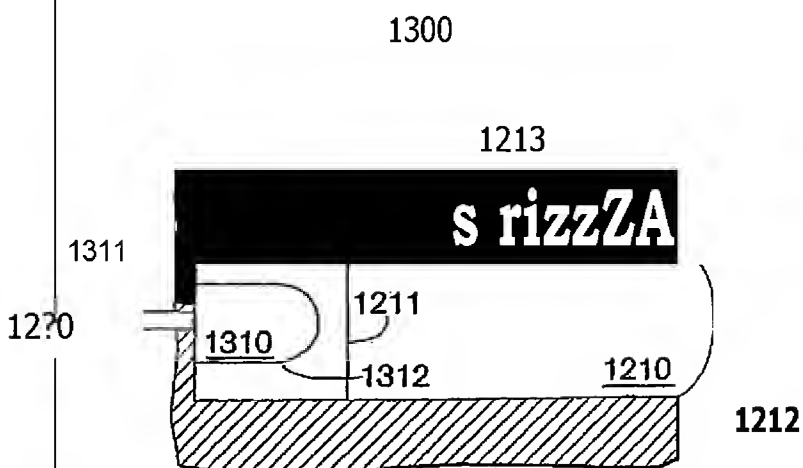

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Fig. 13A

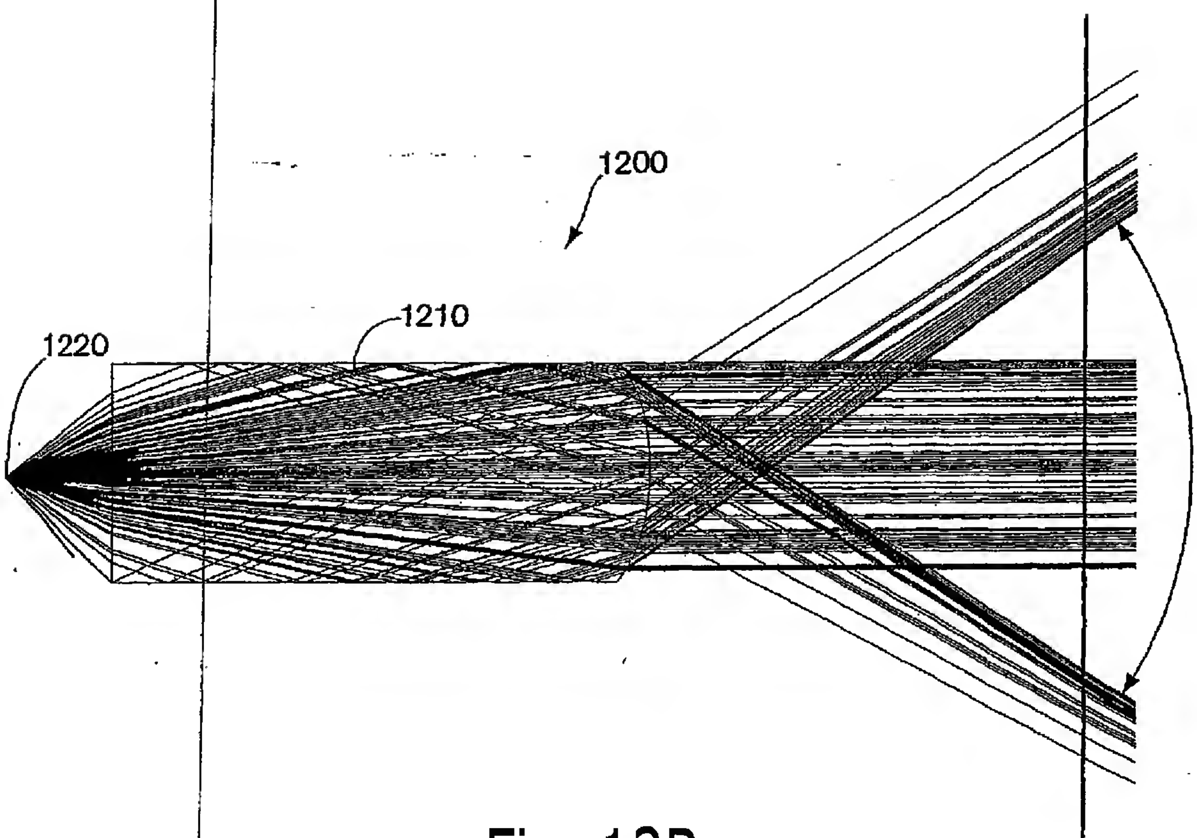


Fig. 12B

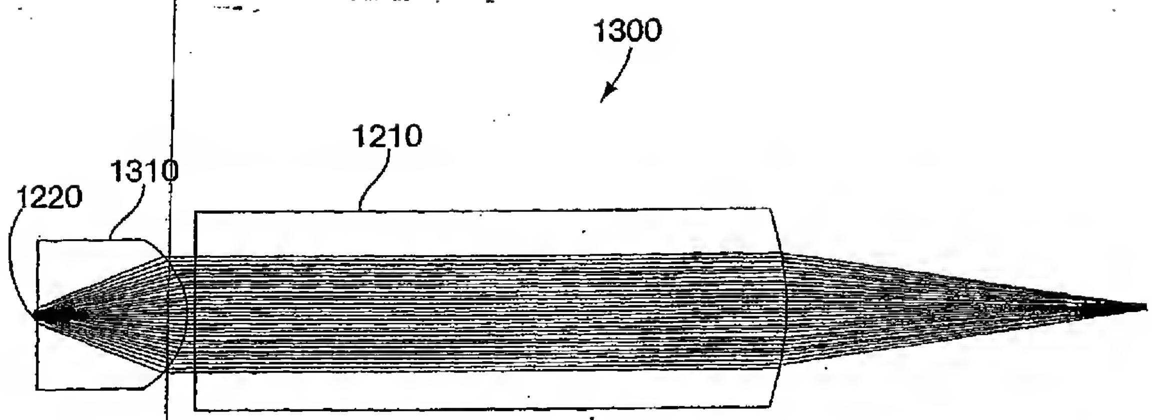


Fig. 13B

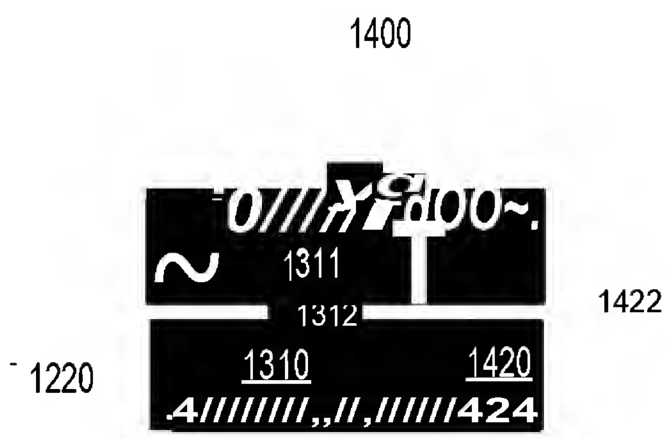


Fig. 14A

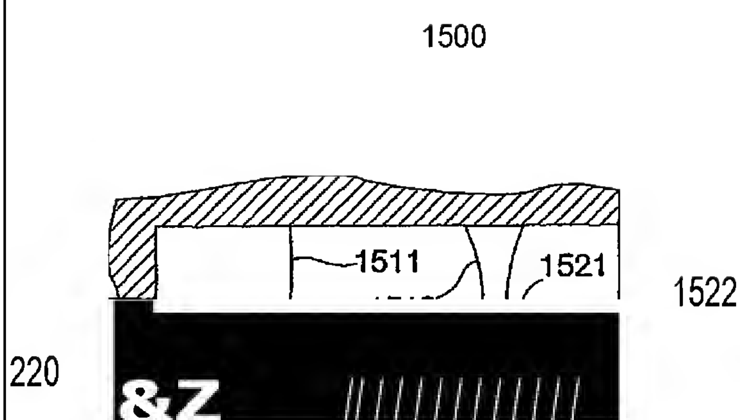


Fig. 15A

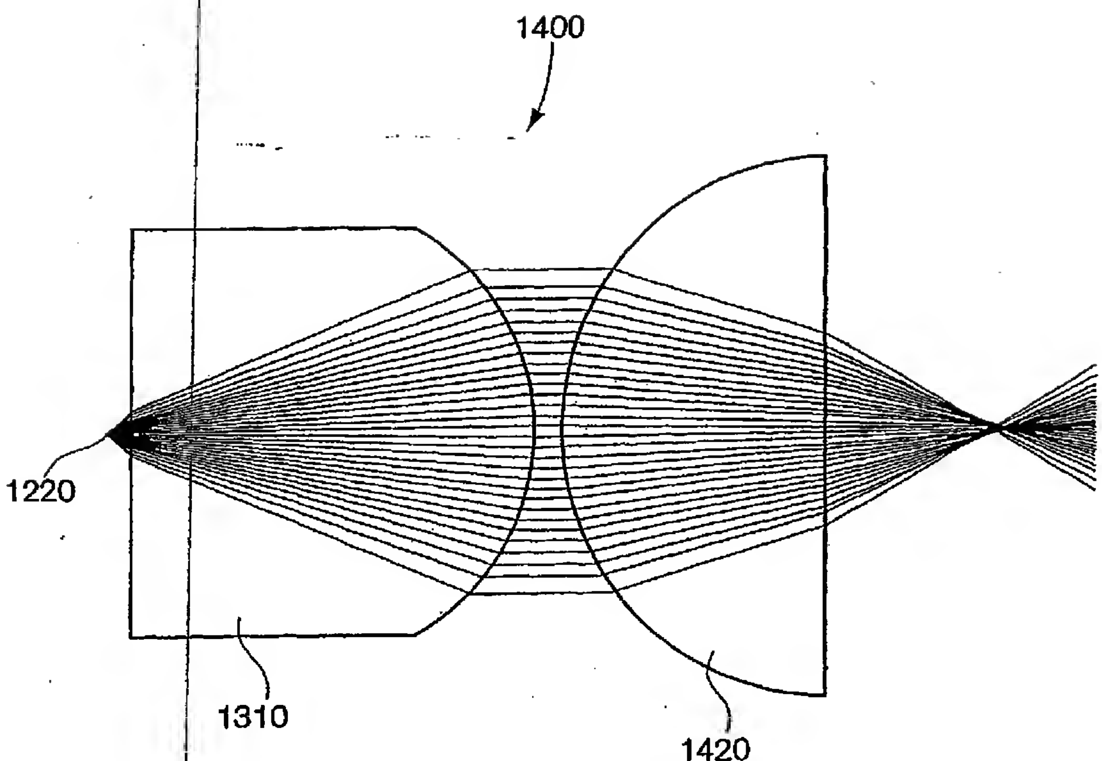


Fig. 14B

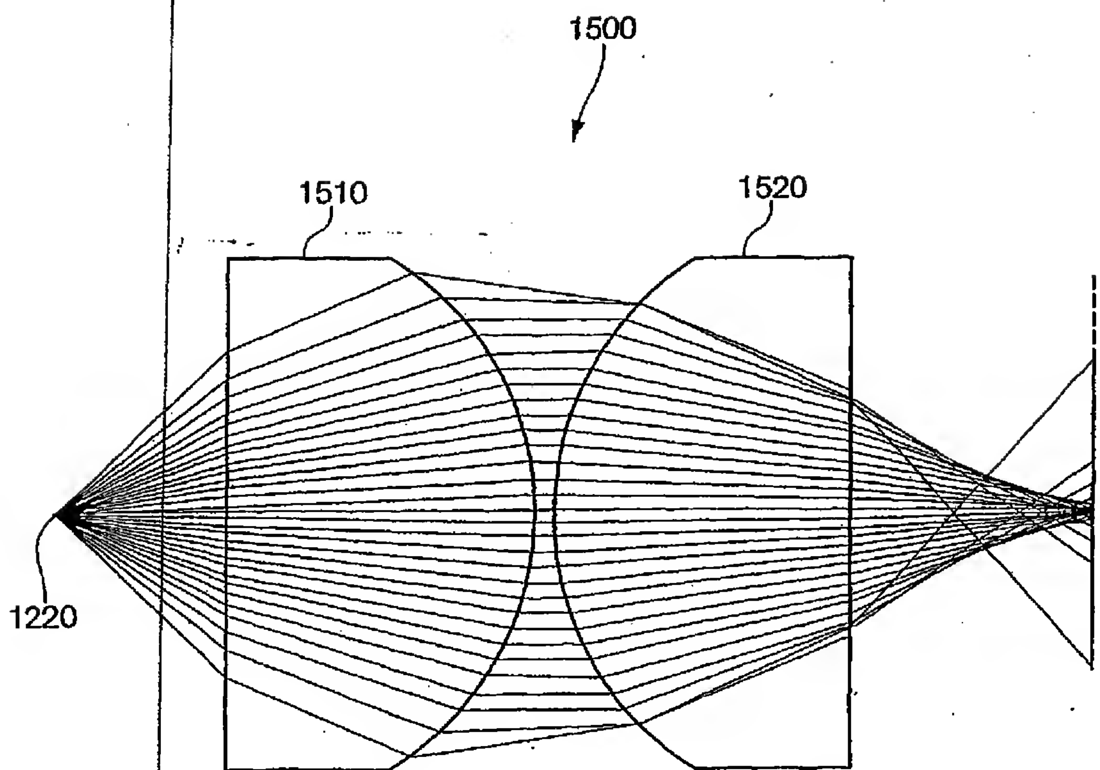


Fig. 15B

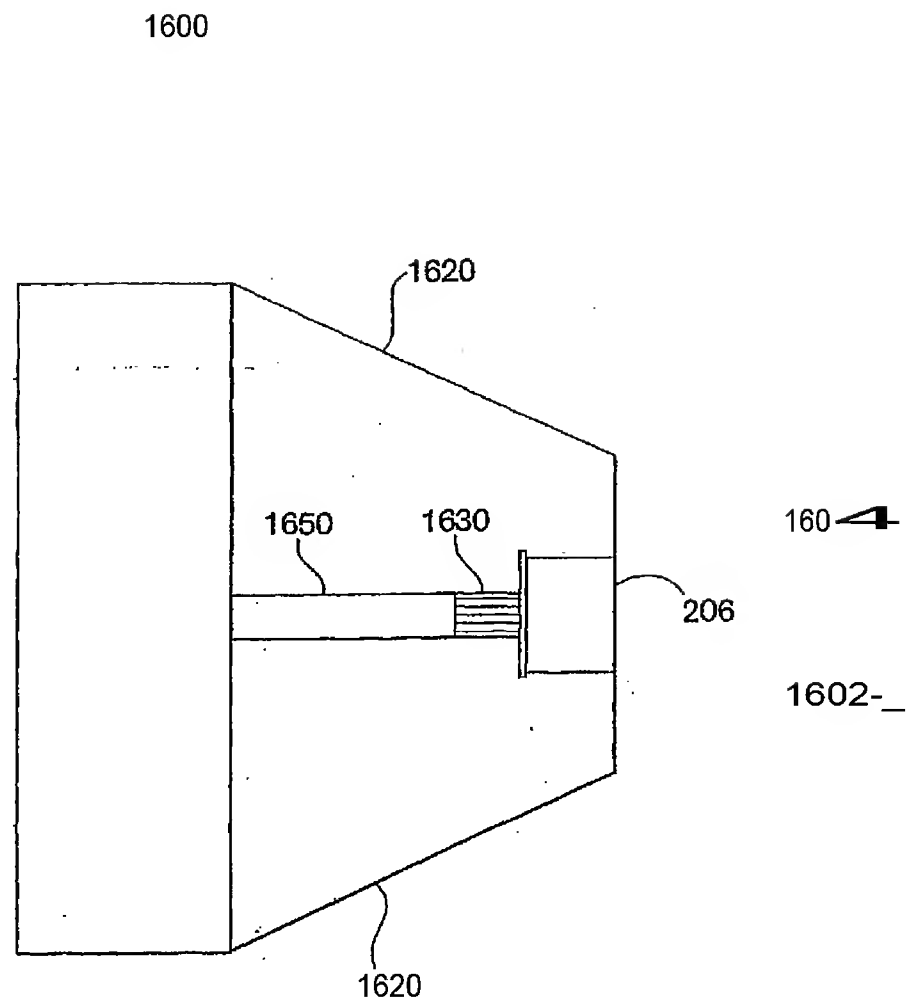


Fig. 16A

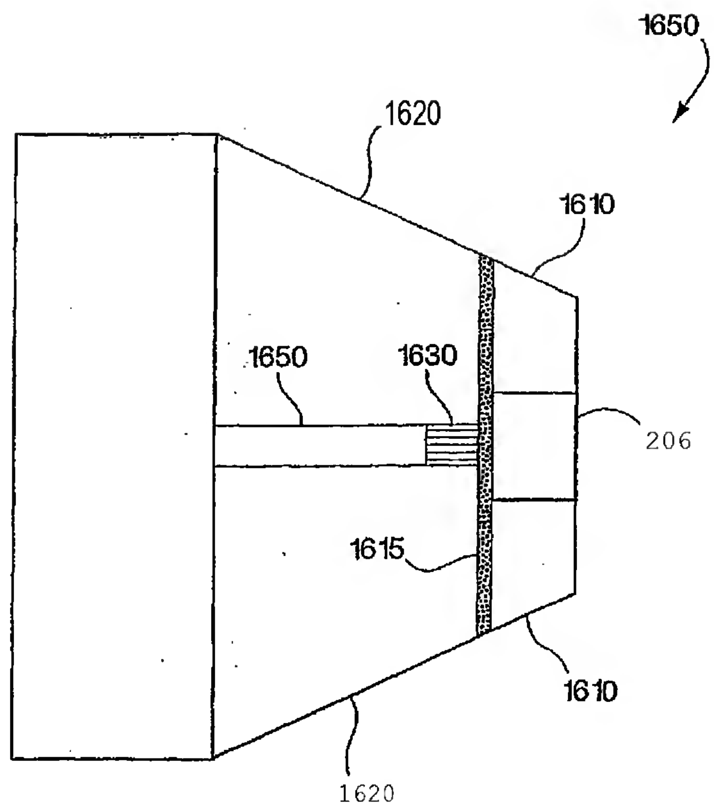


Fig. 16B

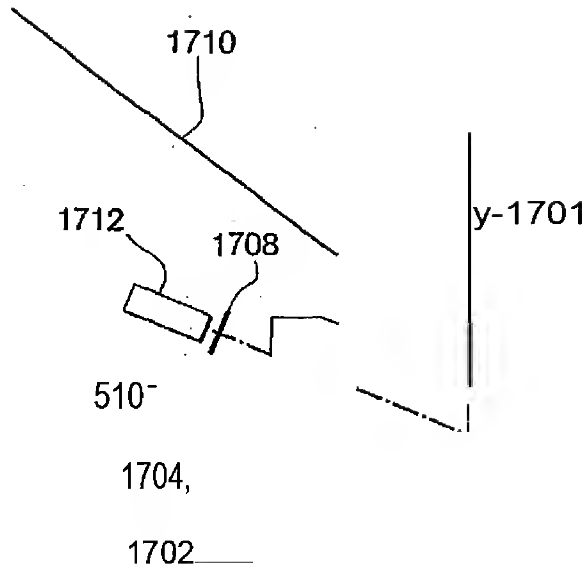


Fig. 17A

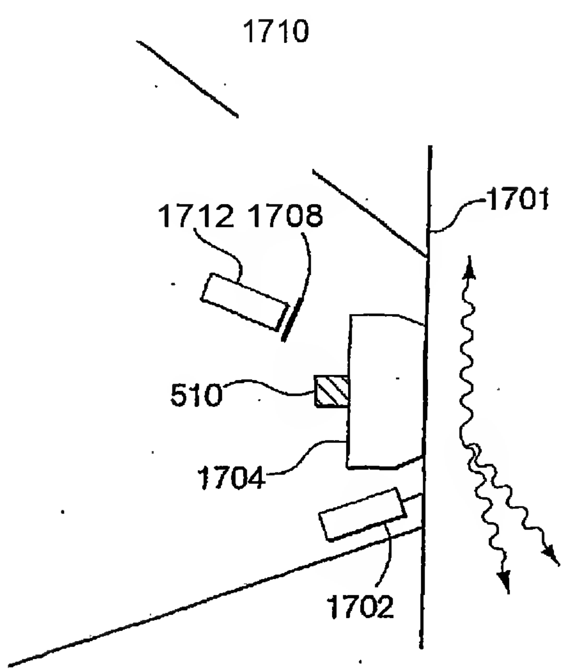


Fig. 17B

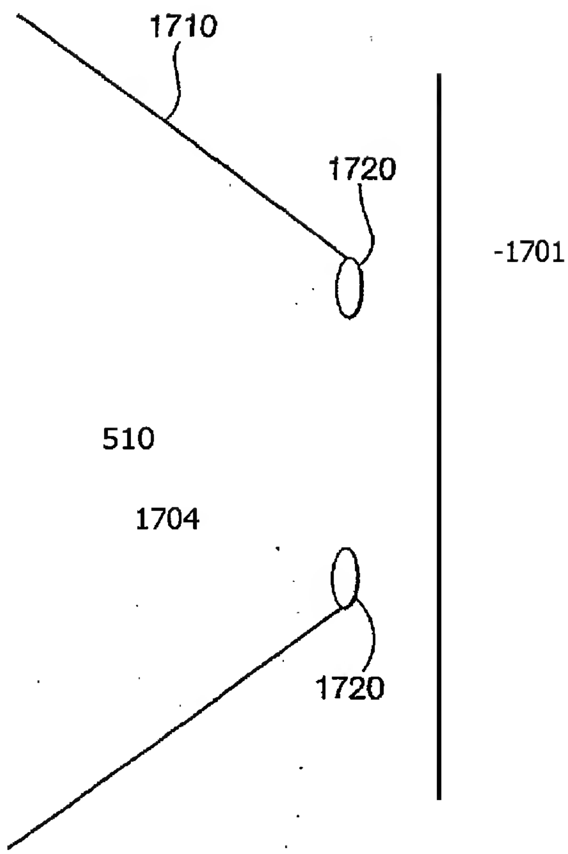
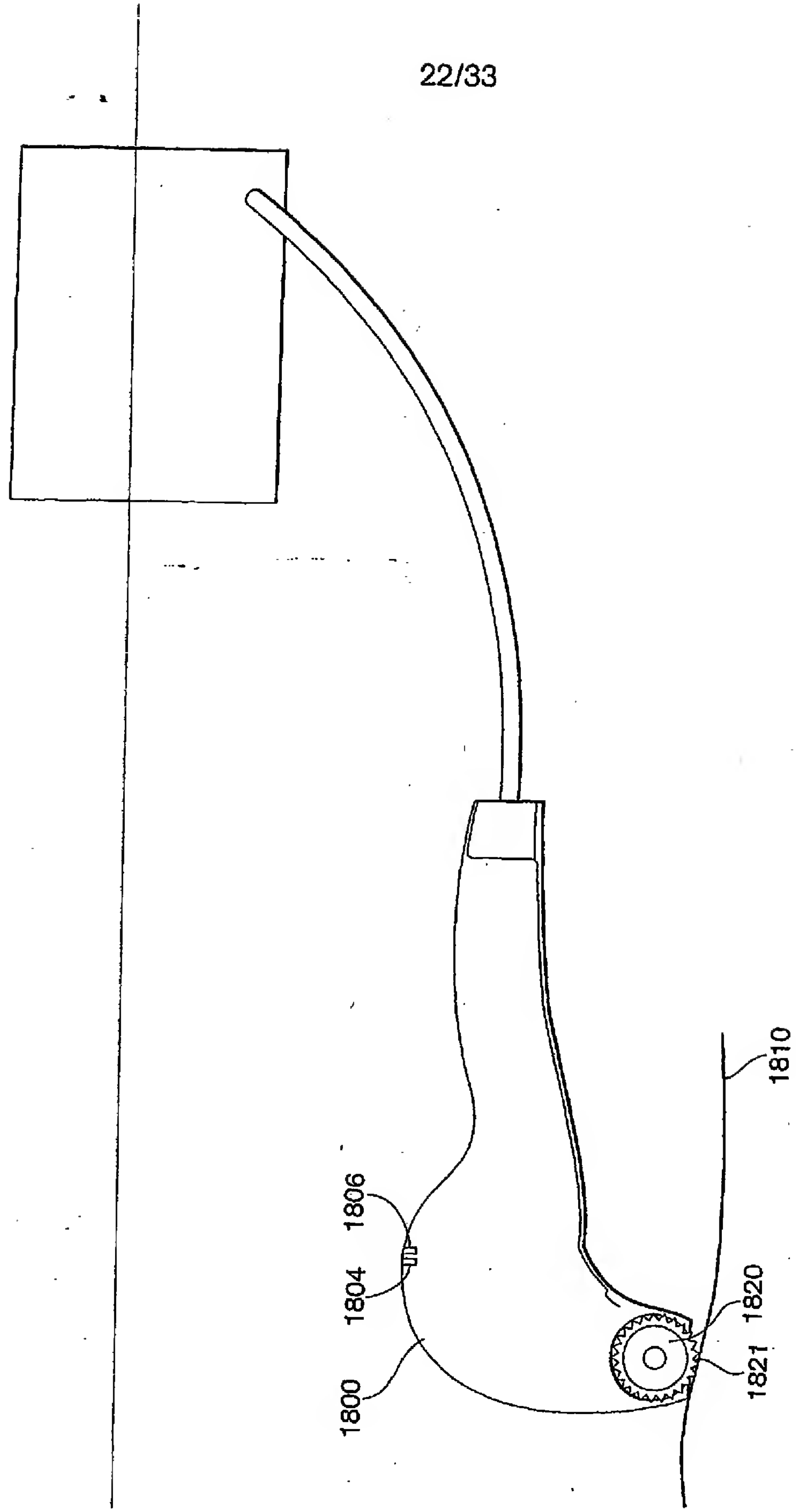


Fig. 17C



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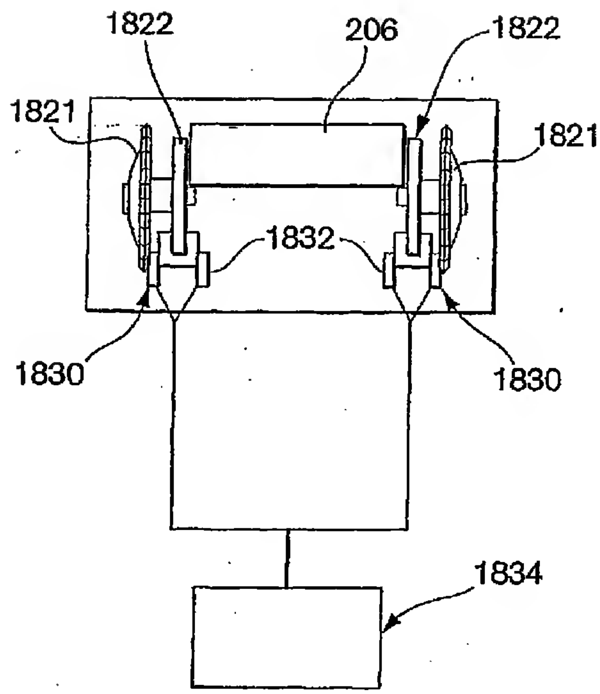
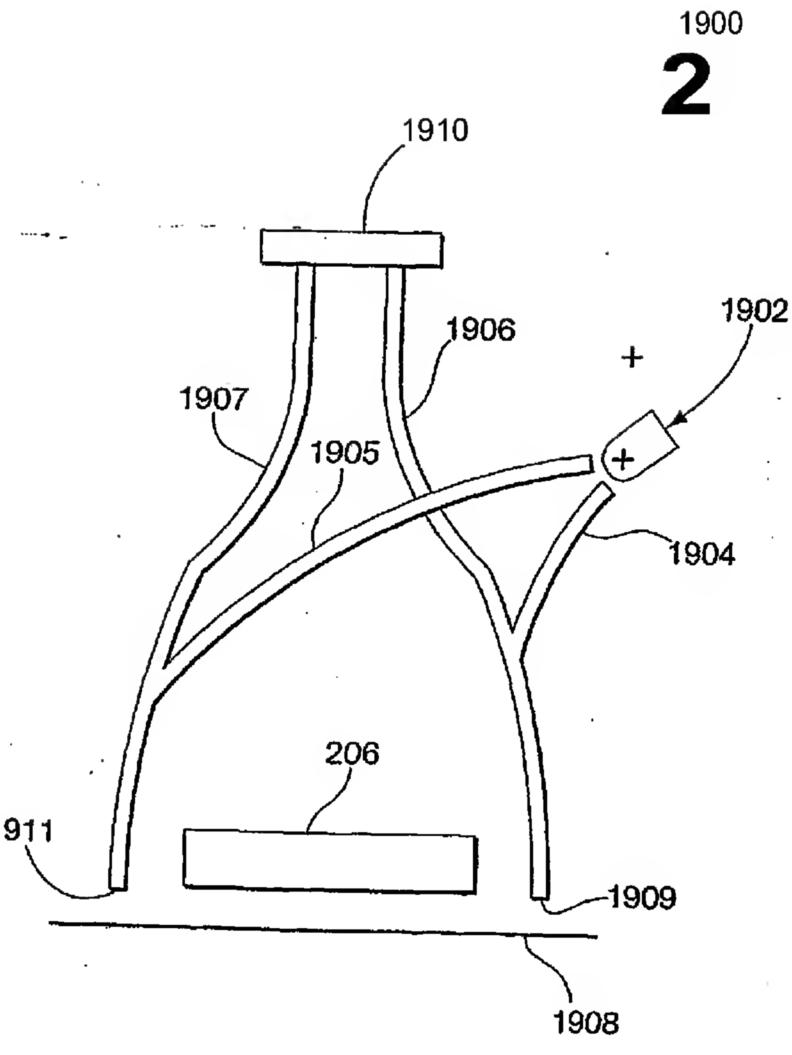


Fig. 18B



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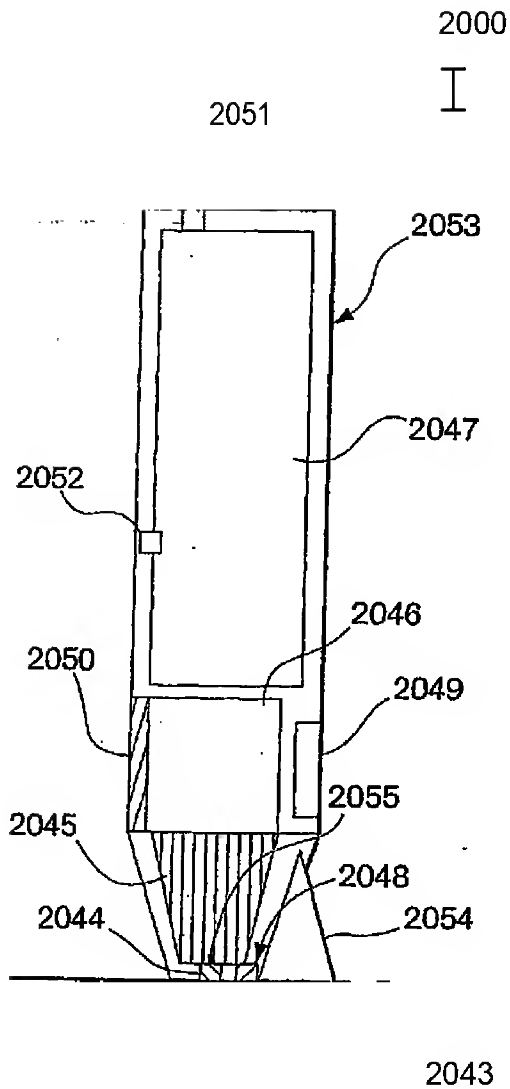
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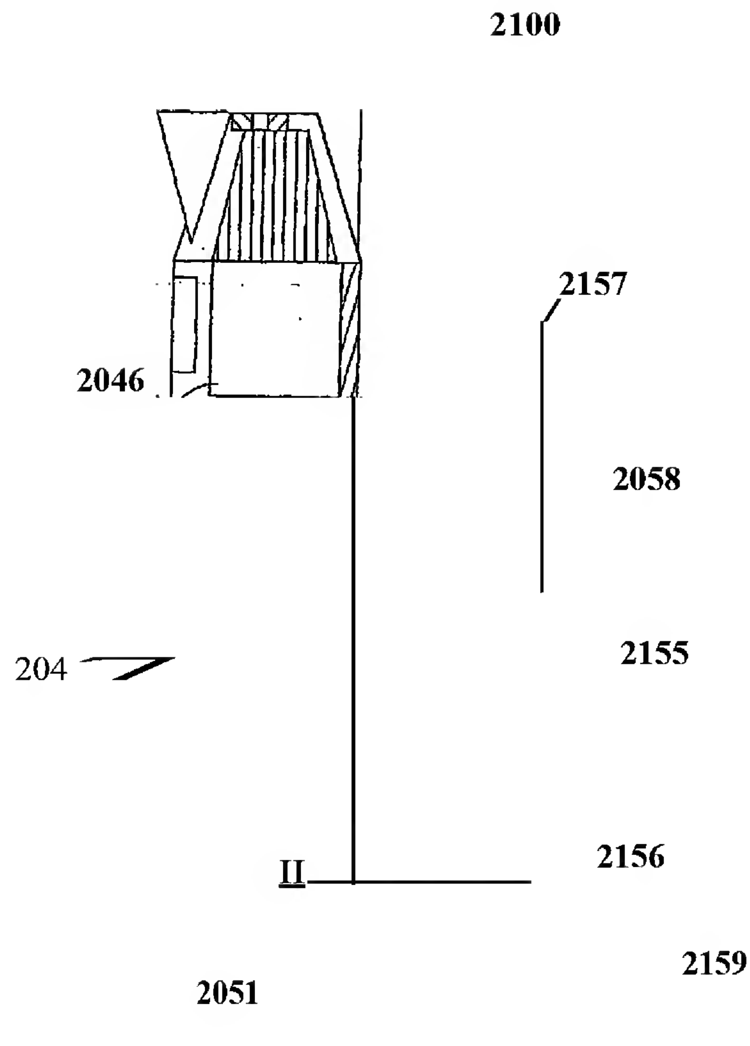
Fig. 20



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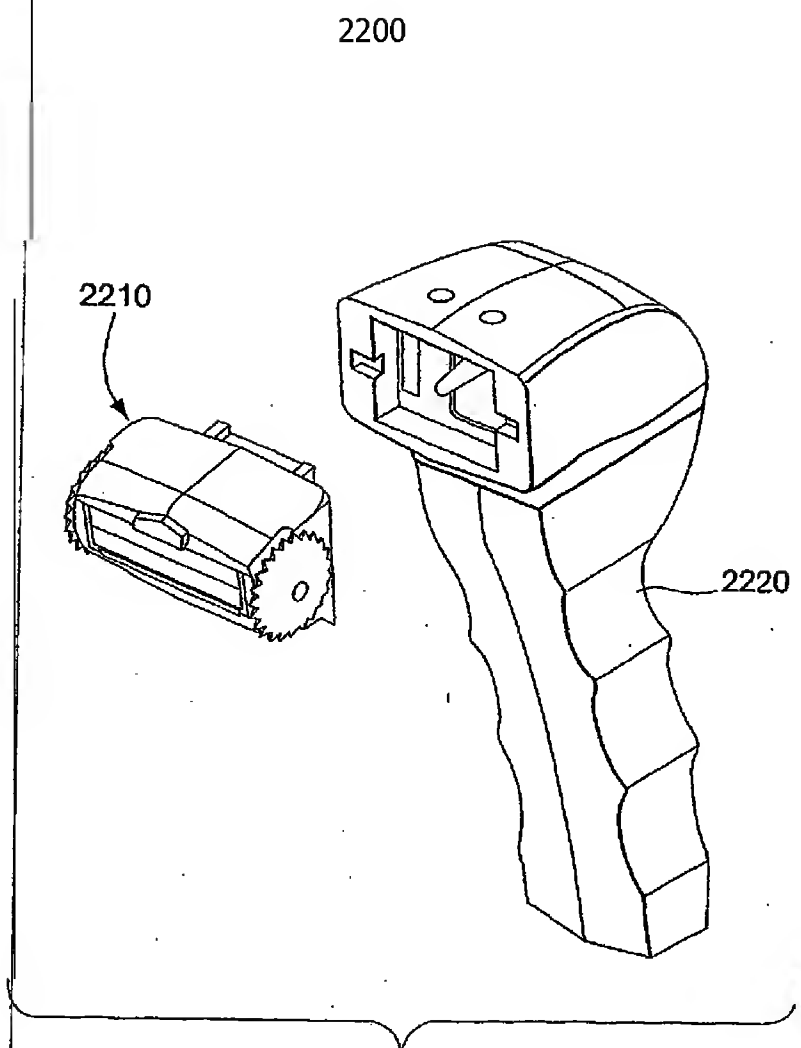

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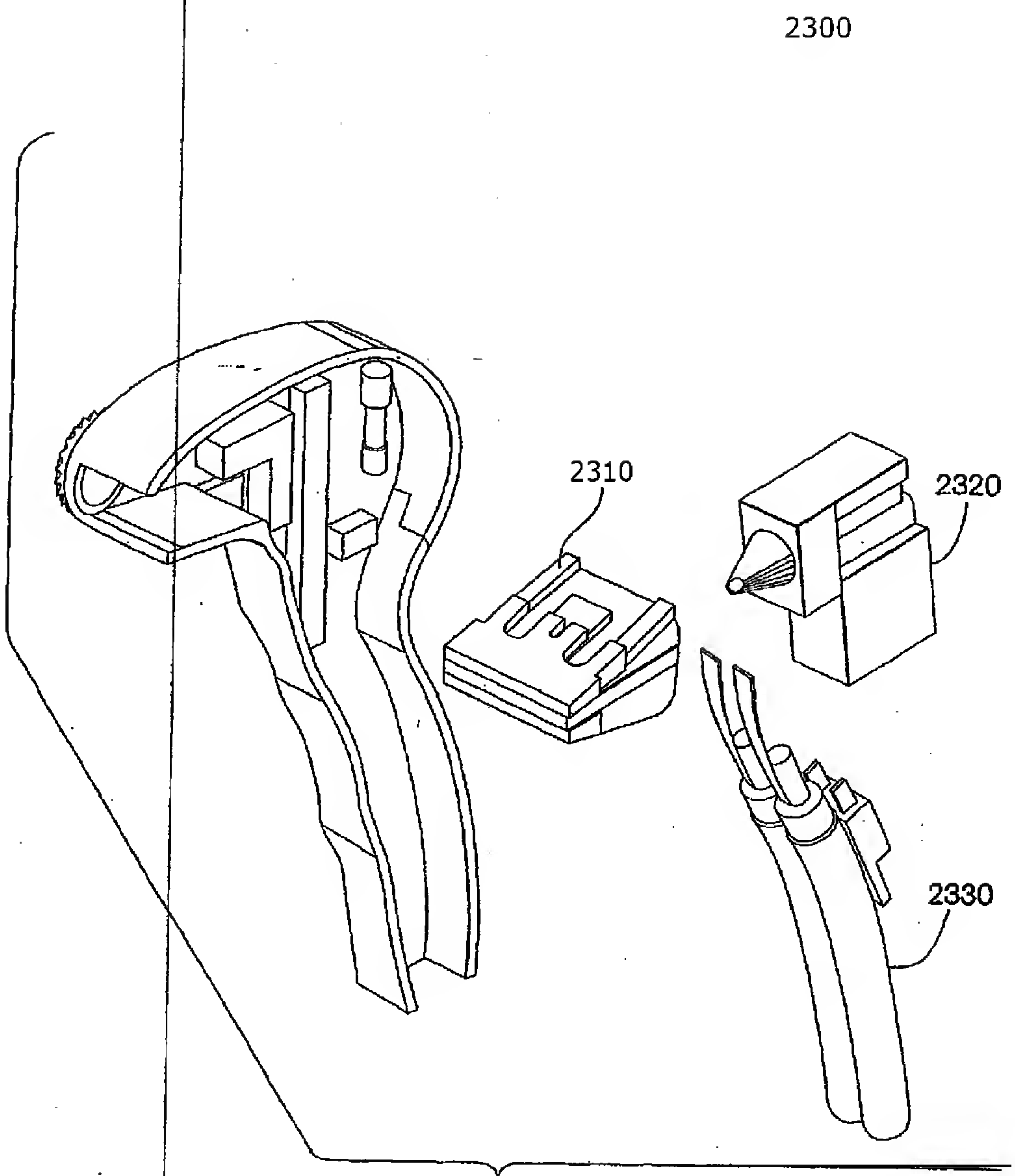
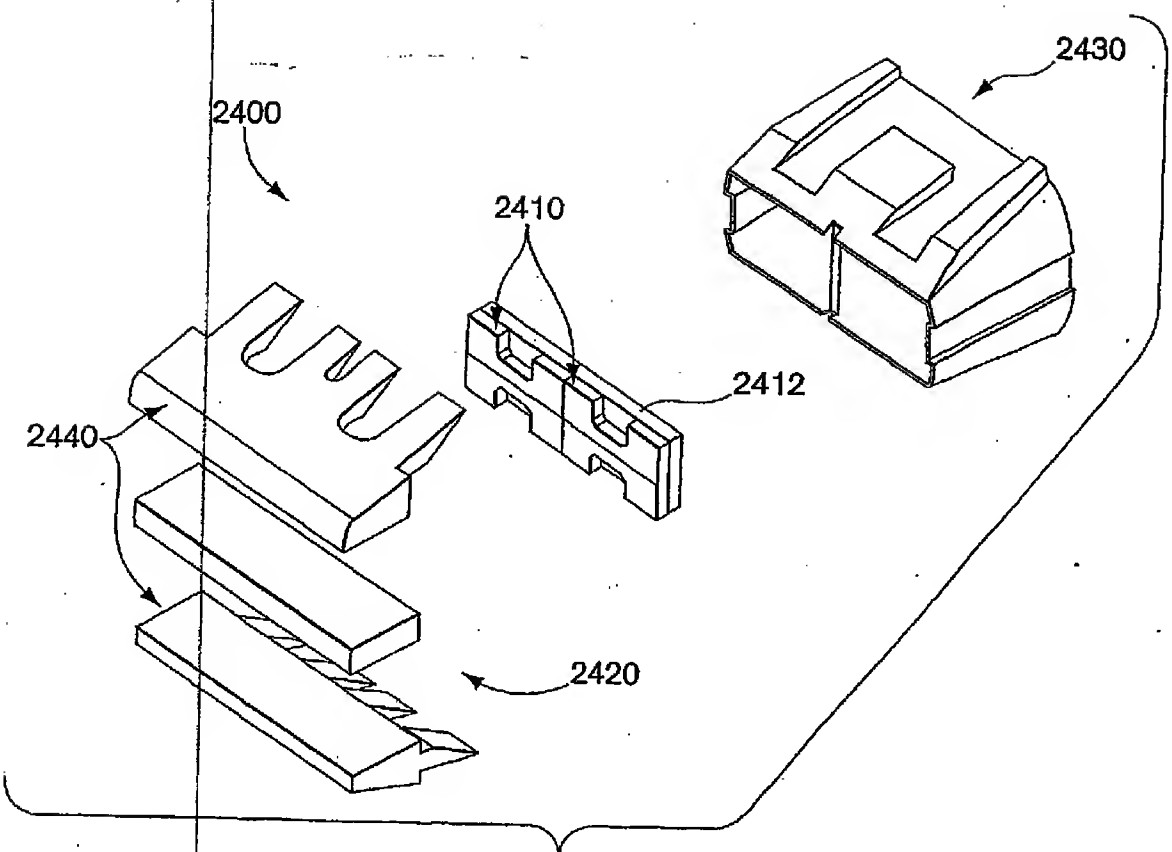


Fig. 23



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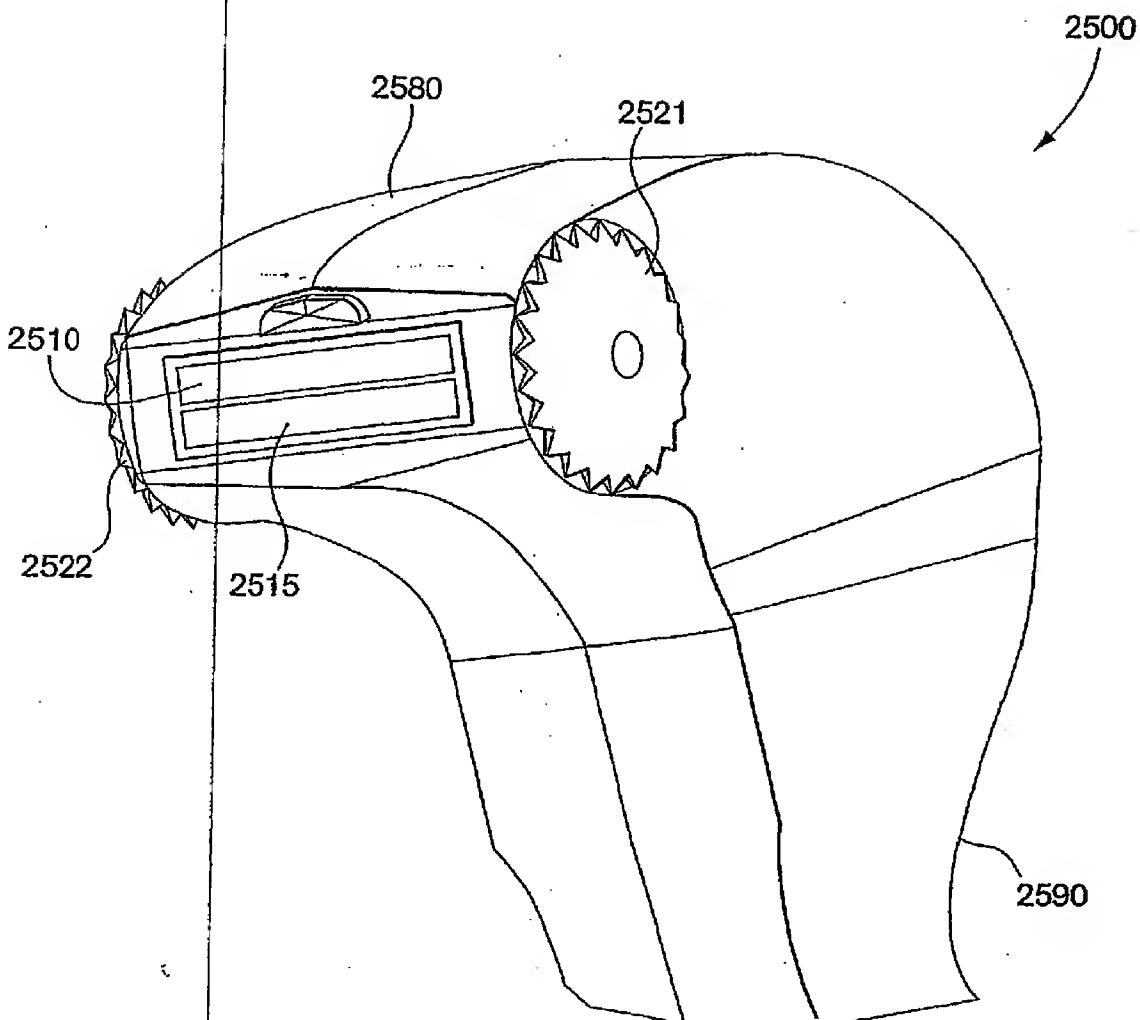

Fig. 25

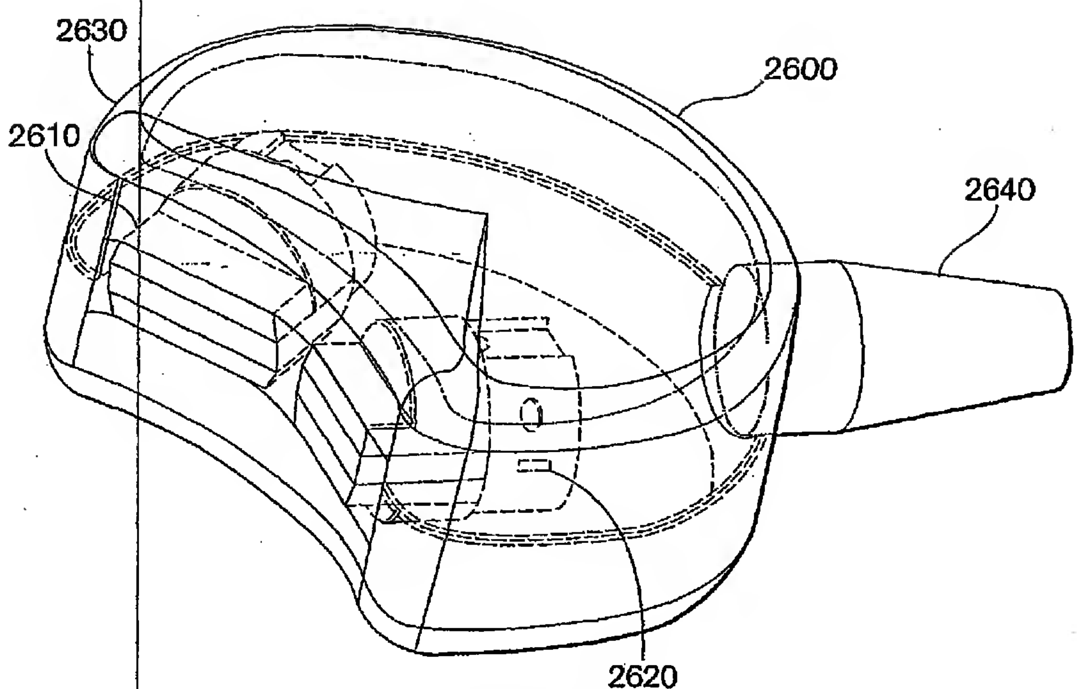

Fig. 26A

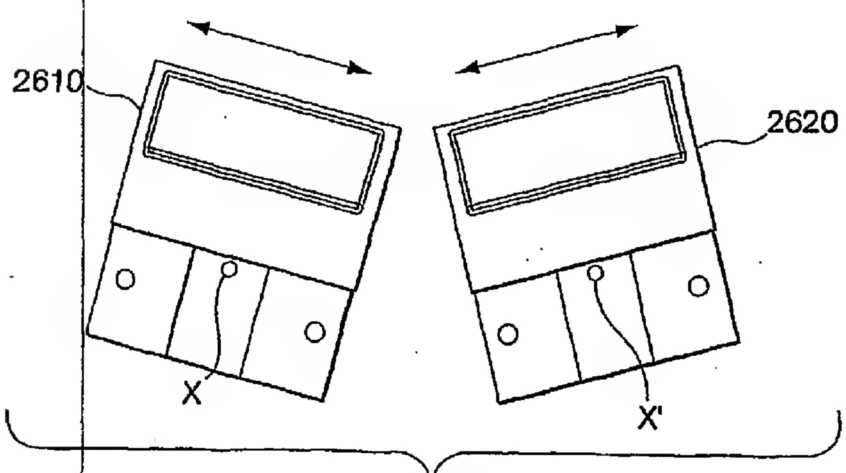

Fig. 26B

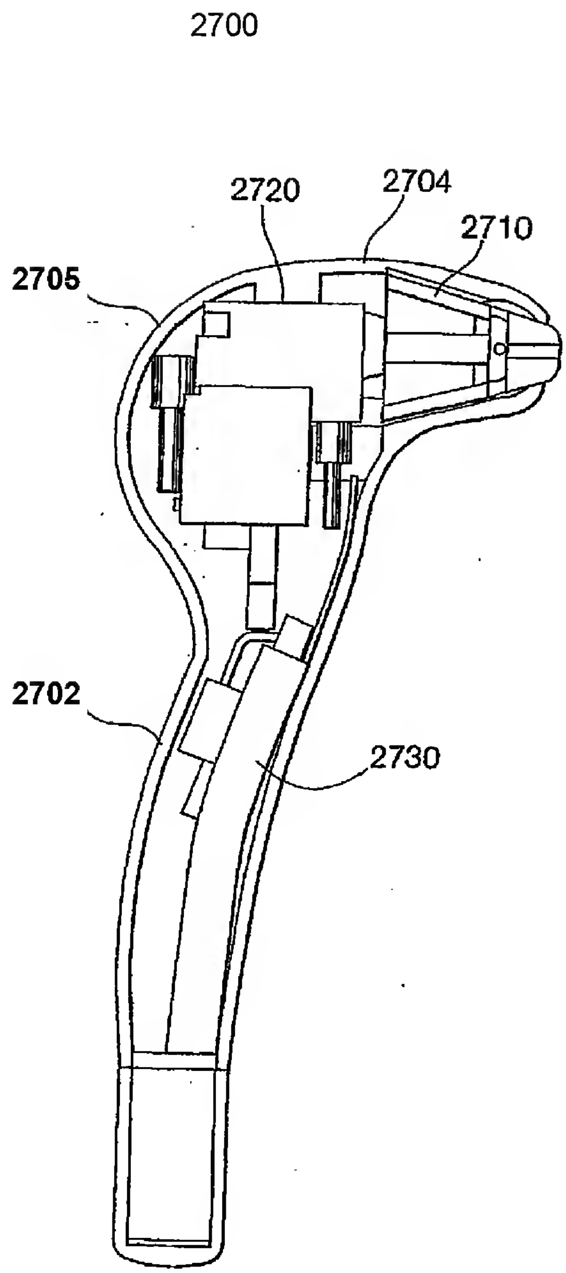

Fig. 27

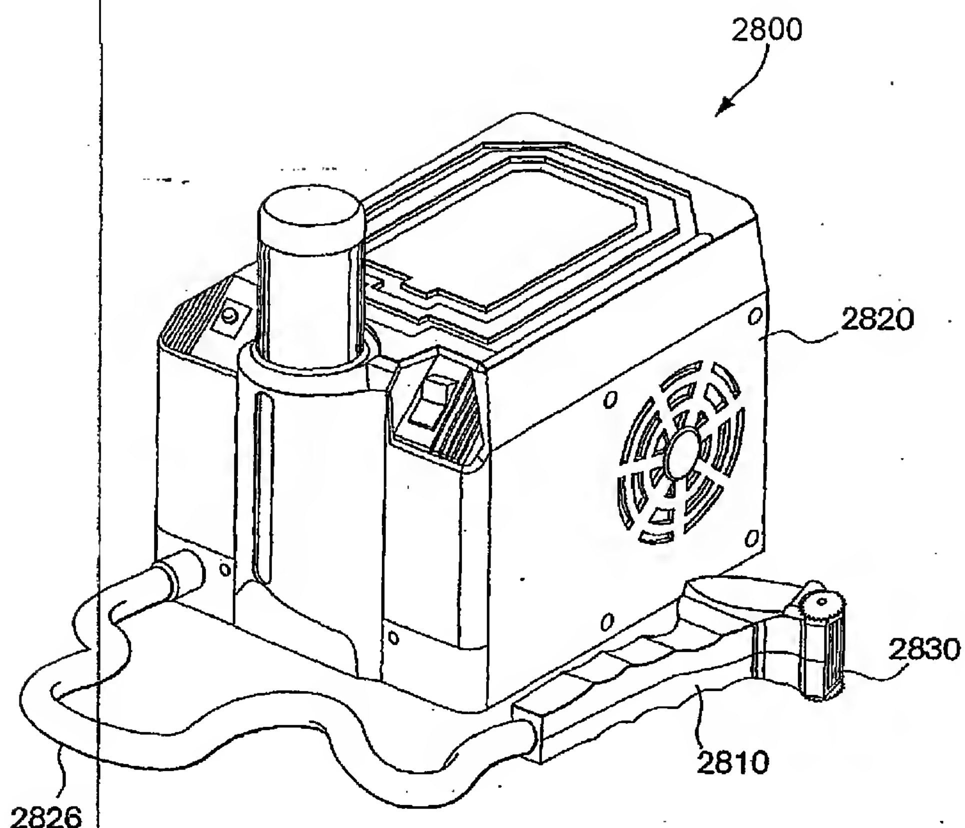

Fig. 28

INTERNATIONAL SEARCH REPORT	International application No. PCT/US02/ 16435

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : A61B 18/18
US CL : 606/9
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 606/9

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
NONE

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,344,418 A (GHAFFARI) 06 September 1994, see entire document	1,11,18,36,38,52
X	US 6,059,820 A (BARONOV) 09 May 2000, see entire document	1,2,8-12,18,19,36,-38,52-54,61,62,64,65
X	US 5,968,033 A (FULLER et al) 19 October 1999, see entire document	21,22,24,28,34
X	US 5,820,625 A (BAUMGARDNER) 13 October 1998, see entire document	1,2;8-13,18,19,36-38,52-54,61,62
A	US 5,810,801 A (ANDERSON et al) 22 September 1998, see entire document	1-65

Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

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Date of the actual completion of the international search 29 July 2002 (29.07.2002)	Date of mailing of the international search report 6 SEP 2002
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Telephone No. 703-308-3520

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